SNe Ia and Their Hosts

Joshua Meyers (Supernova Cosmology Project)

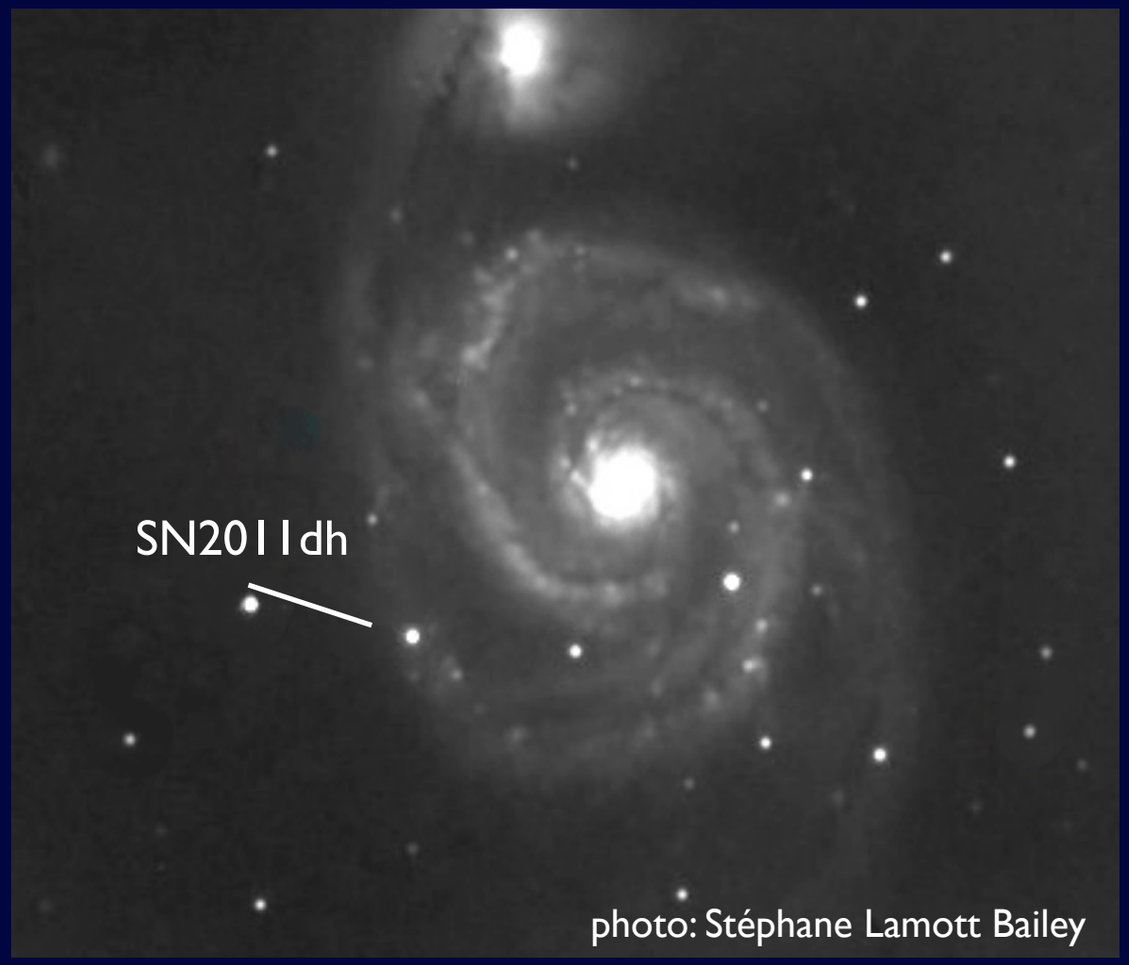
SNe Ia Hosts Outline

- SNe Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations

M51: the very first SN host classification (1845)?

SNe Ia Hosts Outline

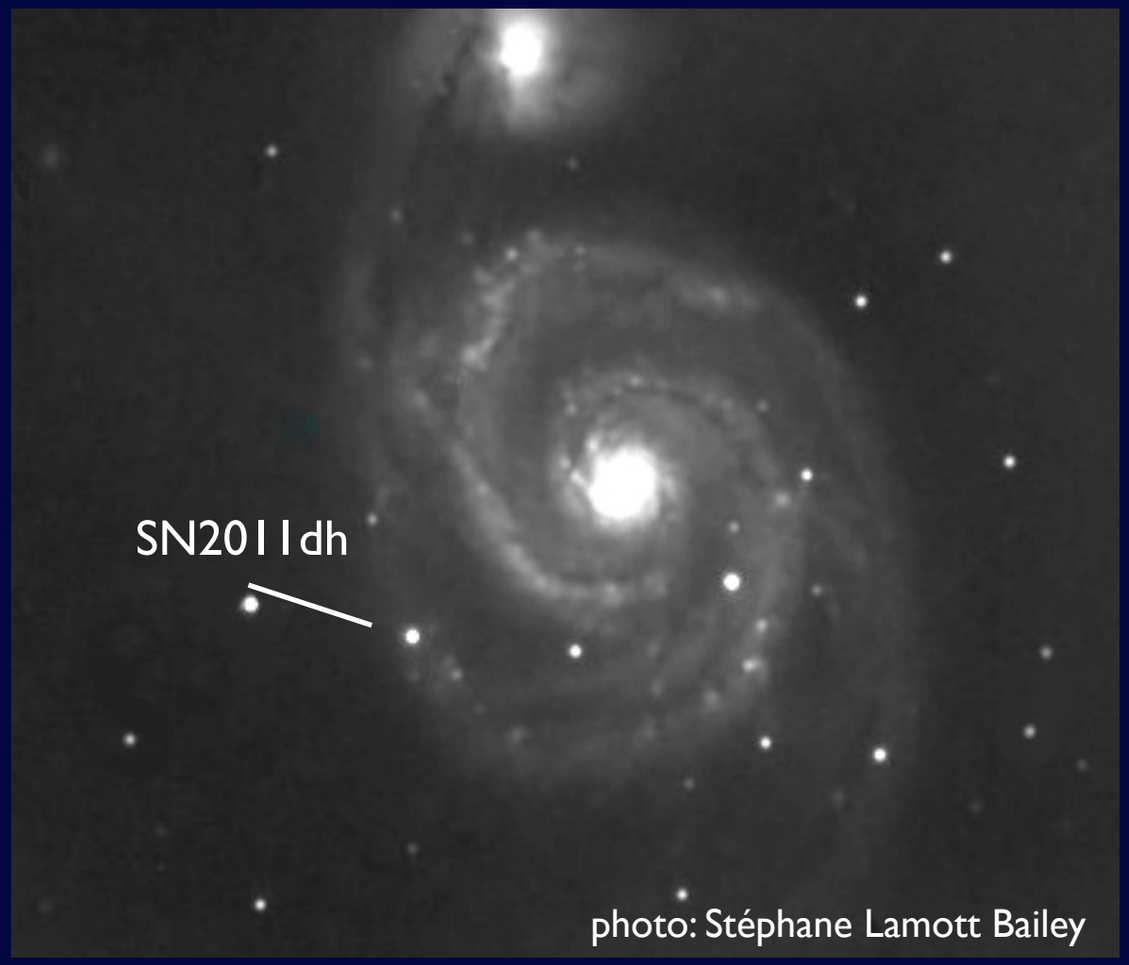
- SNe Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations



M51: the very first SN host classification (1845)?

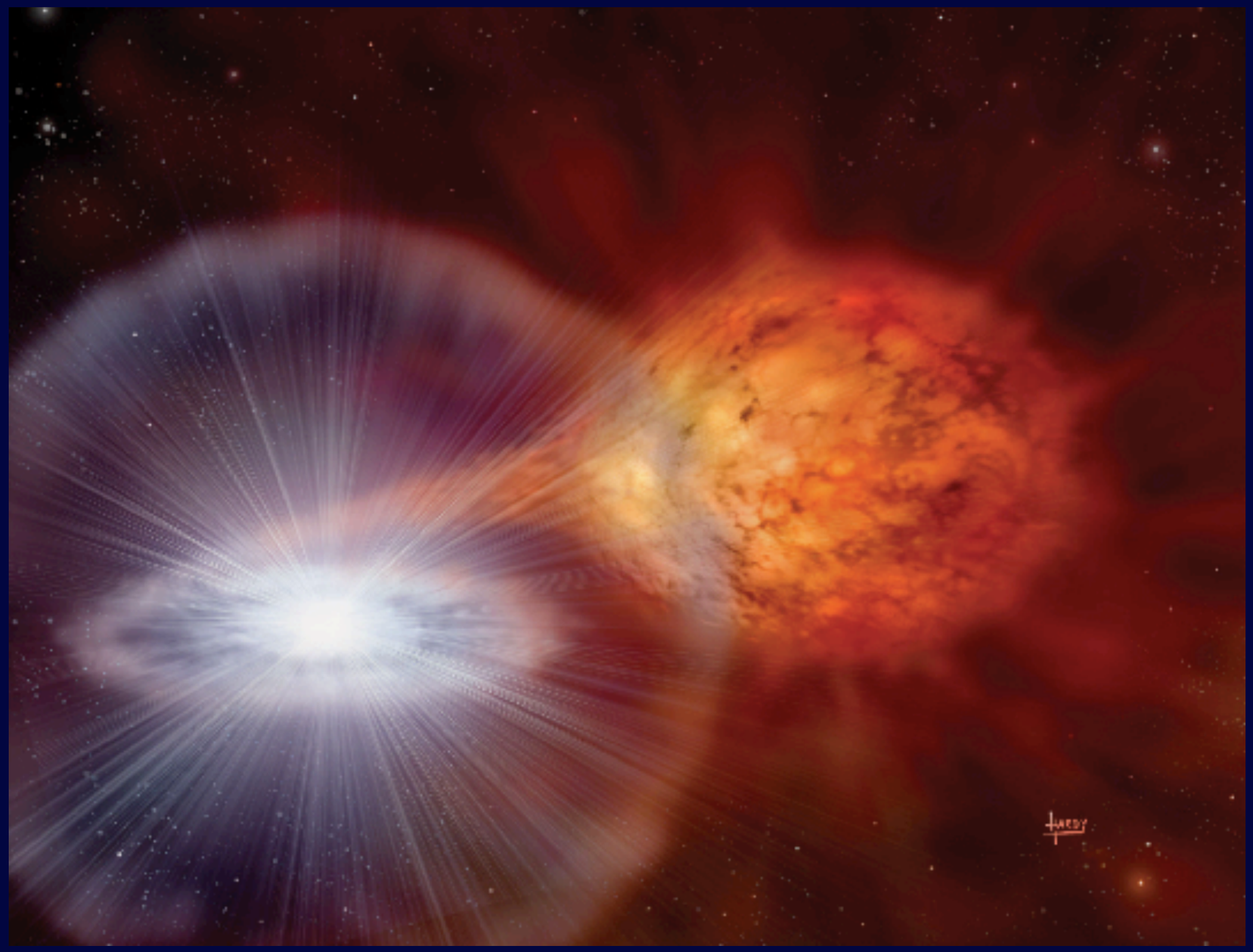
SNe Ia Hosts Outline

- SNe Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations



M51: the very first SN host classification (1845)?

SNe Ia basics



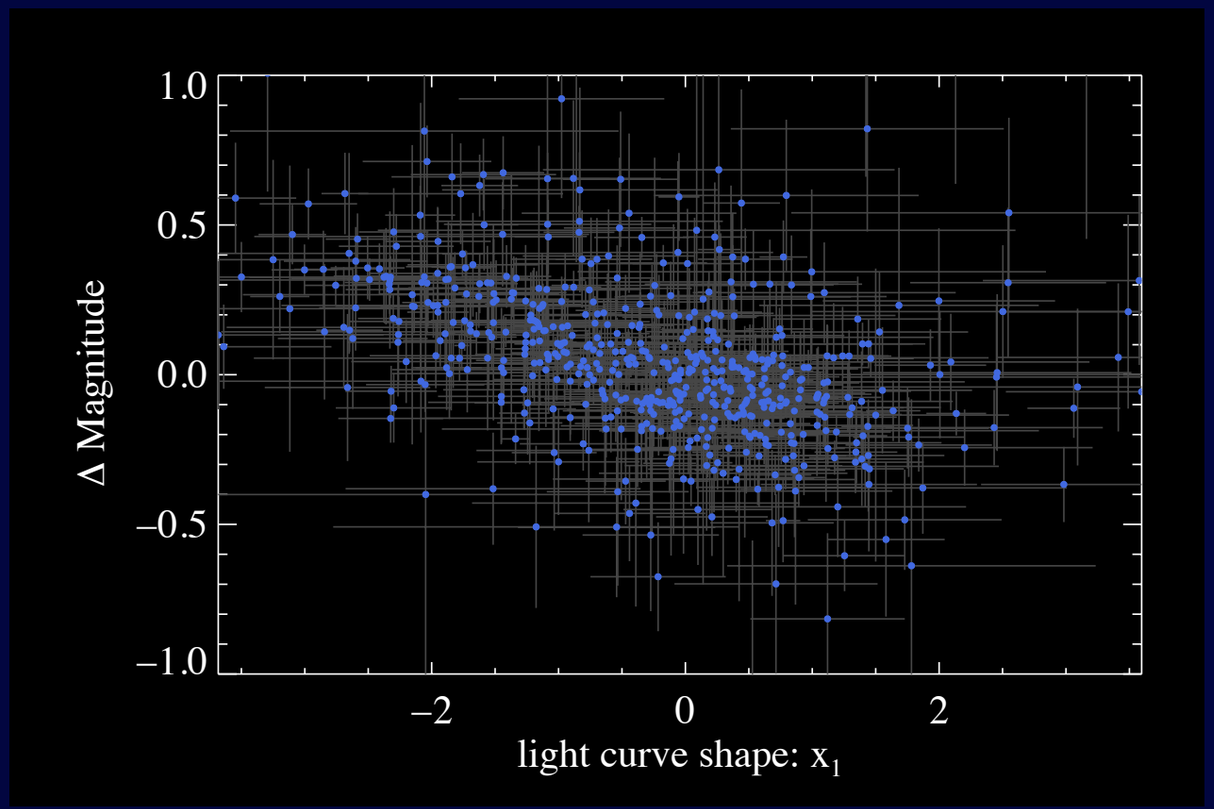
- Type Ia SNe are the thermonuclear disruption of white dwarf stars near the Chandrasekhar limit ~1.4$M_{\odot}$.
- The SN Ia light curve is powered by the decay of ^{56}Ni created in explosion.
- SNe Ia vary in peak brightness by ~0.4 magnitudes.
- Progenitor composition or age could be important.

SN Ia calibration 101

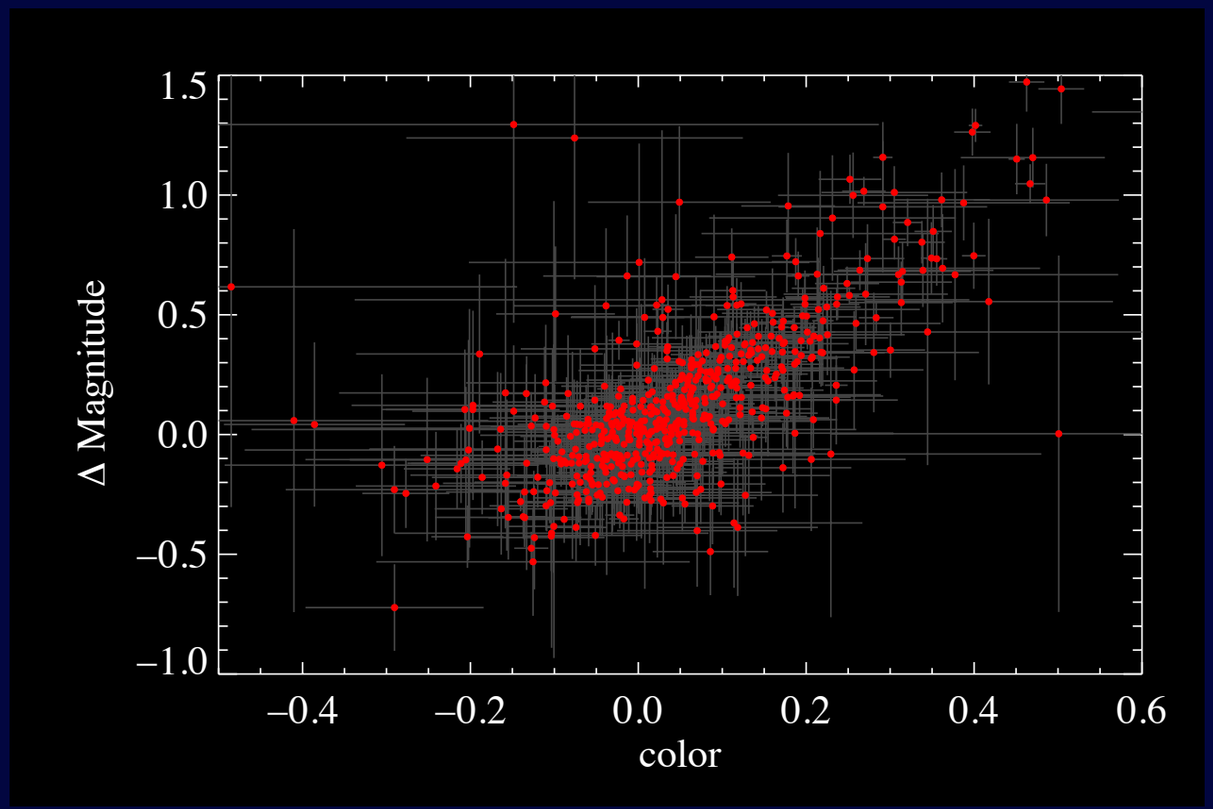
- Distance modulus parameterization (SALT2 (Guy et al. 2011)):

$$\mu = m_B - M_B + \alpha x_1 - \beta c$$

- α: parameterizes the light curve shape (x_1) -- brightness relation
- β: parameterizes the SN color (c) -- brightness relation

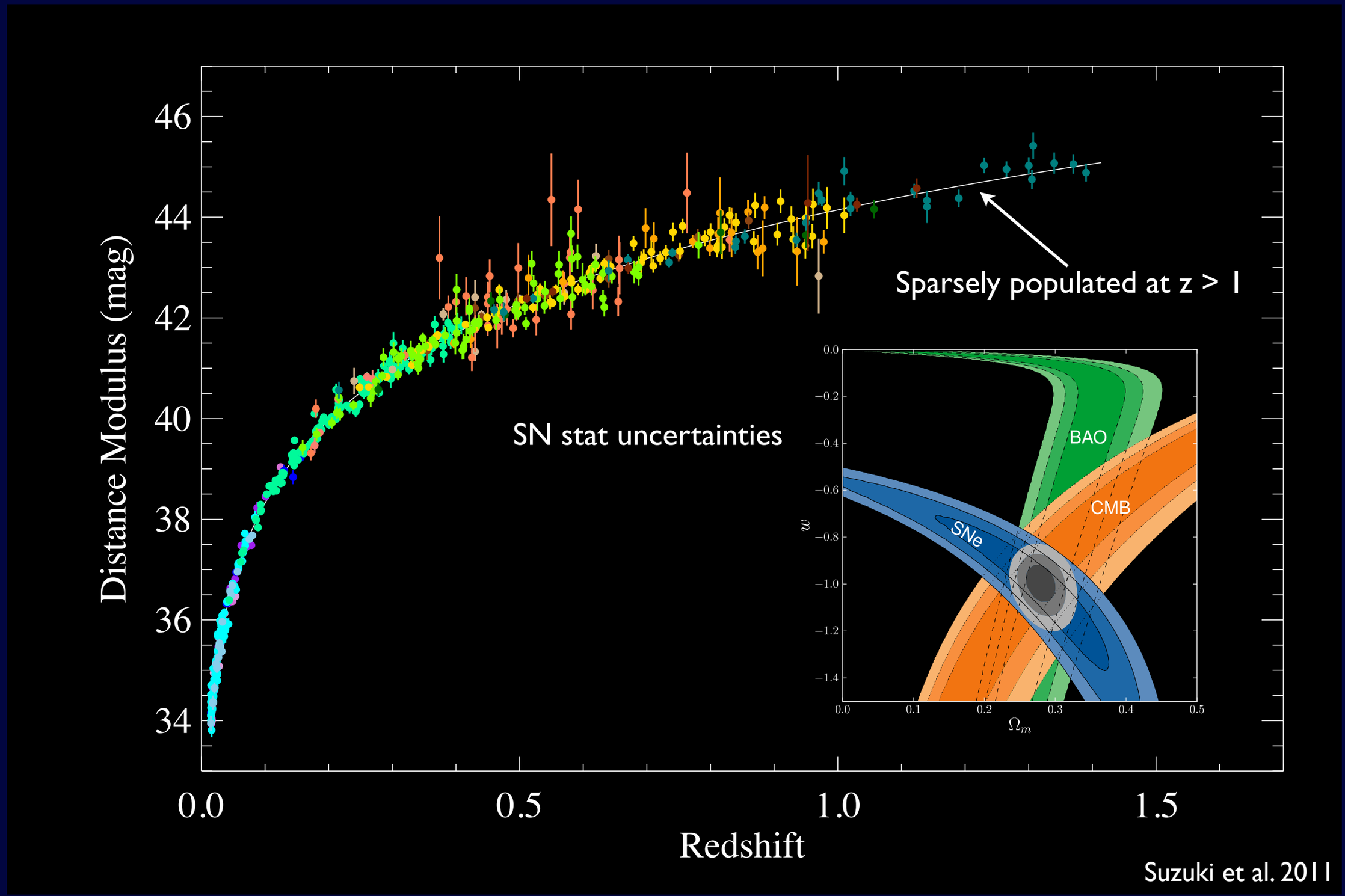


data from Suzuki et al. (2011)



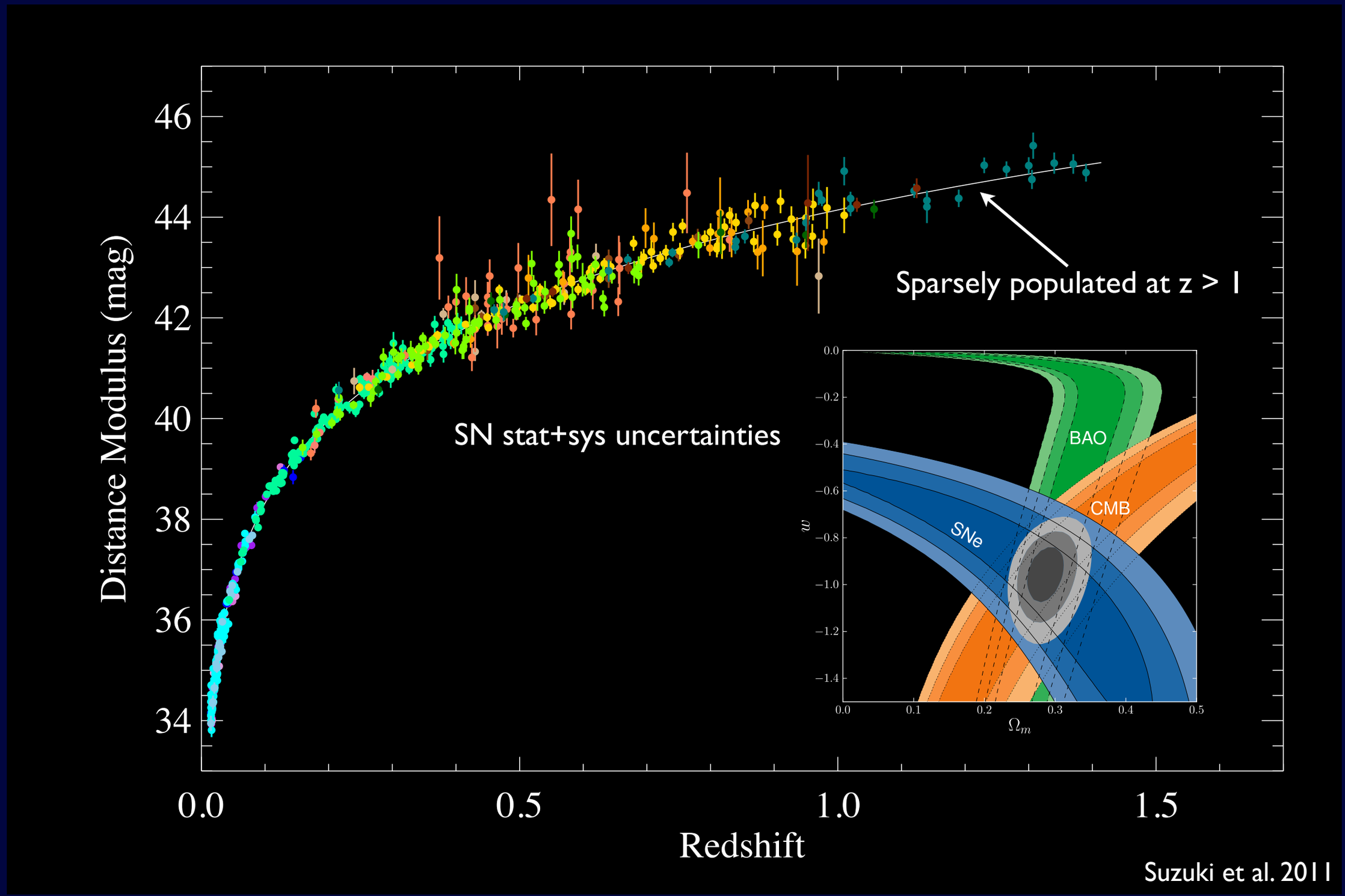
data from Suzuki et al. (2011)

SN Ia Compilation



Suzuki et al. 2011

SN Ia Compilation



Suzuki et al. 2011

Outline

- SN Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations

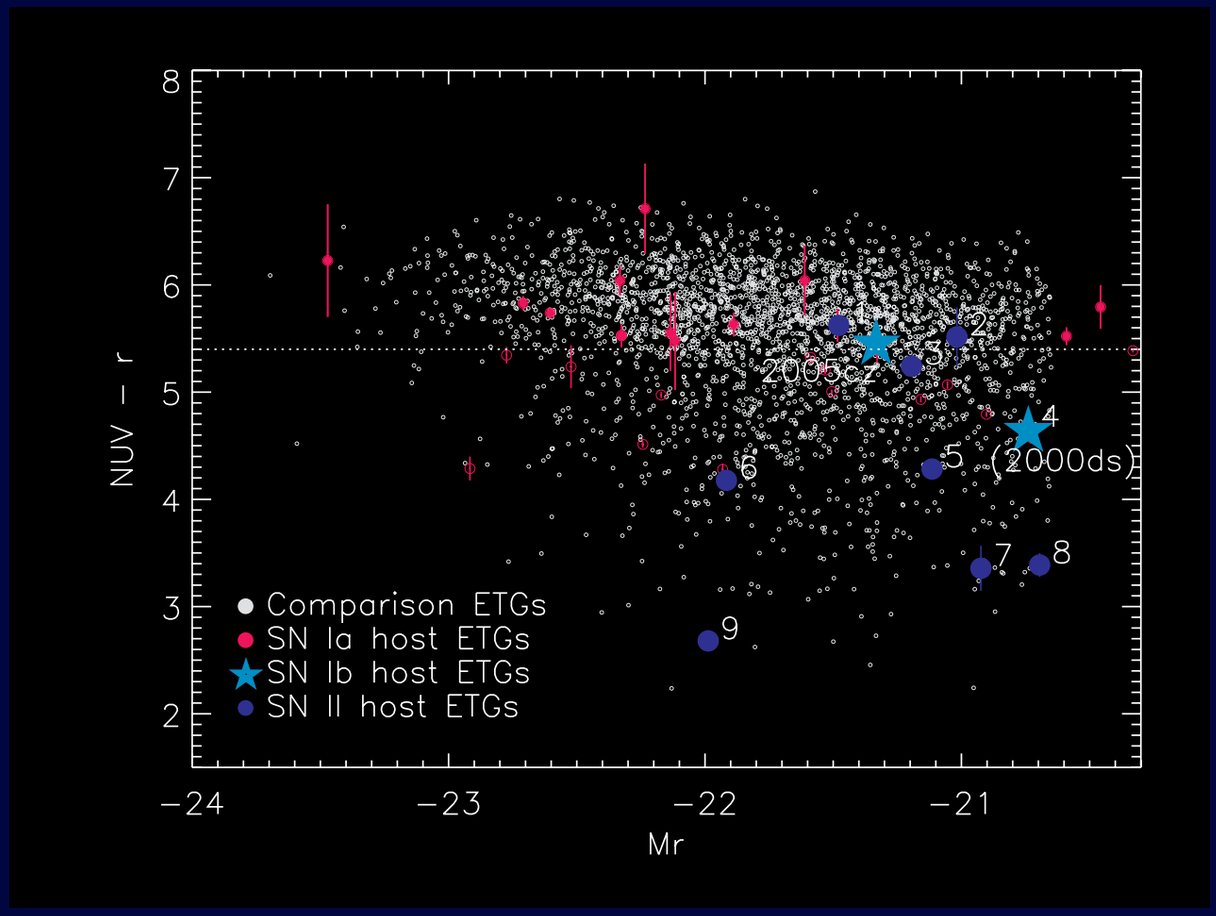
Early-type galaxies do not host core collapse SNe

Hakobyan et al. (2008)

Core collapse SNe with host classifications:	~1000
Hosts classified as early-types:	22
Hosts still classified as early-type after reclassification:	3
Early-type hosts remaining after throwing out SN 2005md:	2

These 2 remaining SNe are both members of a peculiar subclass of faint "Ca-rich" SNe Ib which are typically 4 mag fainter than SNe Ia.

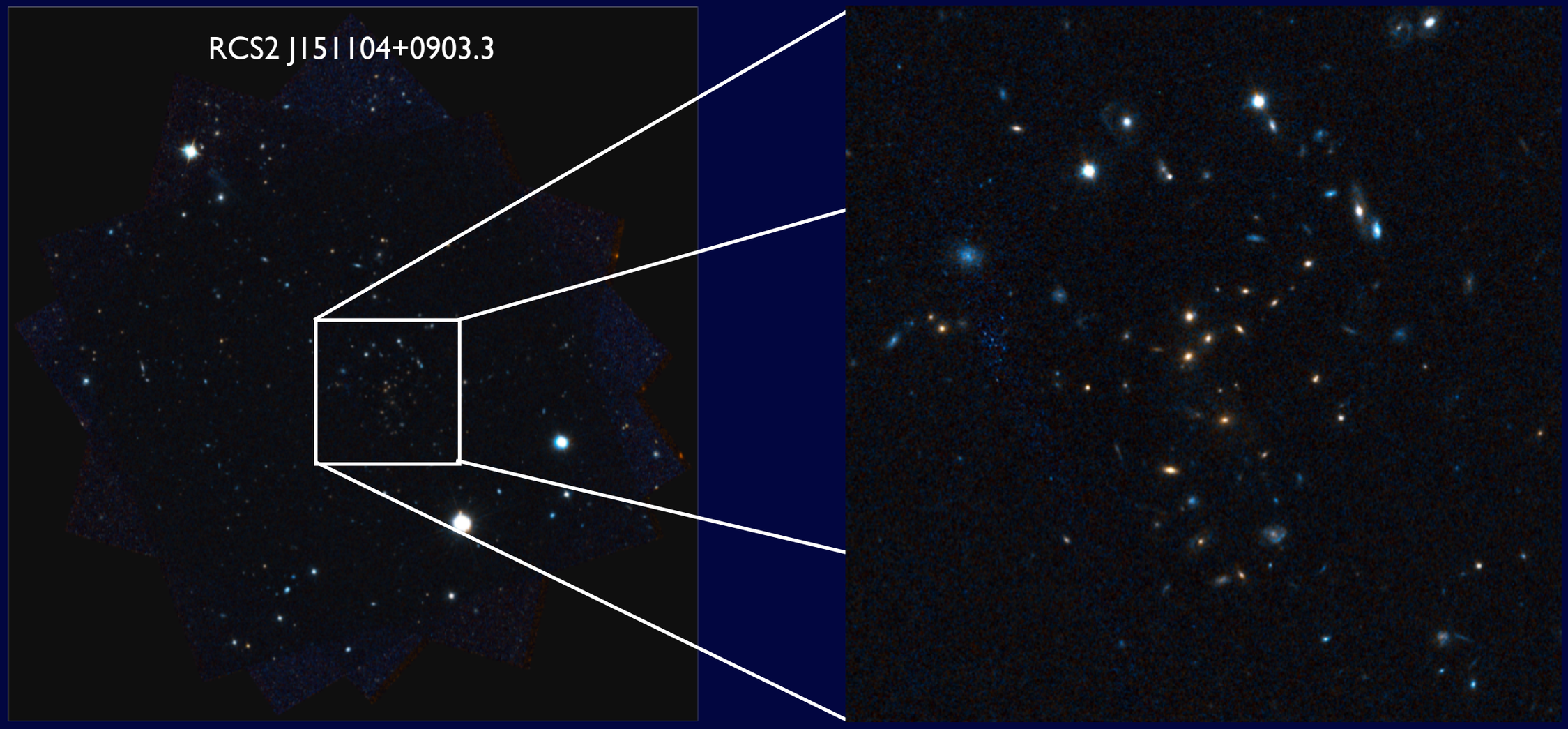
Suh et al. (2011)



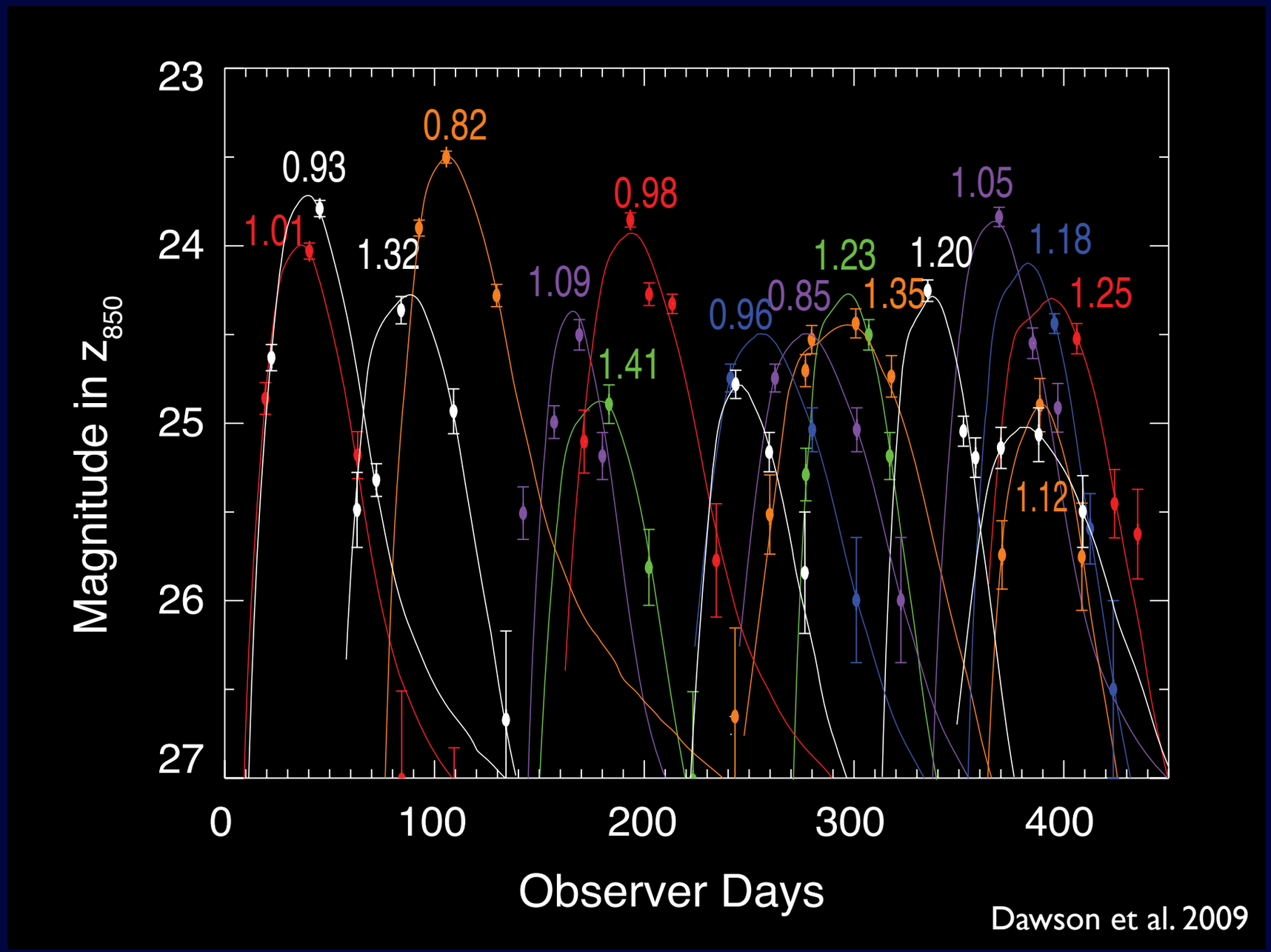
Early-type hosts of core collapse SNe occupy a different region of the NUV - optical color-magnitude diagram than early-type hosts of SNe Ia.

HST Cluster SN Survey

- Clusters are rich in early-type galaxies
- 219 orbits in ACS i_{775}, z_{850}, and NICMOS J_{110}
- 25 clusters ($0.9 < z < 1.5$), about 8 epochs each
- Over 350 spectroscopically confirmed cluster members



SNe from HST Cluster SN Survey



- 18 z > 0.9 SNe
- 16 are likely SNe Ia (typing from host, light curve constraints and spectroscopy)
- 7.5 in clusters, 6.5 of these hosted by early-type galaxies
- 8.5 in the field, 4 of these hosted by early-type galaxies

Direct estimate of relative rates of SNe Ia and SNe CC

Galaxy SN Ia rate

$$R_{SN_{Ia}} = AM + B\dot{M}$$

Sullivan et al. (2006)

Galaxy SN CC rate

$$R_{SN_{CC}} = C\dot{M}$$

Bazin et al. (2009)
Hopkins and Beacom (2006)

- i_{775}, z_{850} => Host mass
- [OII] luminosity => star-formation rate
- LOSS luminosity functions (Li et al. 2011) => visible fraction

Typing by host results

TABLE 2
A PRIORI RATE ESTIMATES FOR EARLY-TYPE SCP SN HOST GALAXIES

Name	log(Mass)	median SFR $M_\odot yr^{-1}$	median $R_{SN\ CC}$ [a] $10^{-3} yr^{-1}$		median $R_{SN\ Ia}$ [a] $10^{-3} yr^{-1}$		P(CC)	Notes
SN SCP05D0	10.9	1.93	0.47	(12.44)	3.11	(4.51)	0.13	s,L
SN SCP05D6	11.4	9.26	0.84	(59.57)	9.20	(17.35)	0.08	L
SN SCP06A4	10.7	1.04	0.13	(6.70)	1.79	(2.87)	0.06	L
SN SCP06C0	11.2	7.99	1.51	(51.37)	8.13	(12.13)	0.15	L
SN SCP06G4	11.2	0.42	0.03	(2.71)	4.78	(9.27)	< 0.01	s,L
SN SCP06H5	11.6	1.16	0.15	(7.46)	12.42	(21.32)	0.01	L
SN SCP06K0	11.4	1.18	0.09	(7.57)	5.09	(14.86)	0.02	L
SN SCP06K18	11.8	0.61	0.05	(3.92)	11.14	(32.58)	< 0.01	
SN SCP06R12	10.4	0.07	< 0.01	(0.44)	0.81	(1.38)	0.01	L
SN SCP06U4	11.1	27.01	6.87	(173.73)	11.94	(17.90)	0.36	s,L

[a] Rates in parentheses are *intrinsic* quantities. Rates not in parentheses are *apparent* and factor in SN detectability.
[s] Spectroscopically confirmed SN Ia.
[L] Light curve shape, color and magnitude consistent with Type Ia (Barbary et al. 2010).

Meyers et al. (submitted)

- Seven of ten z > 0.9 early-type hosted SNe have P(CC) < 10%
- Two of remaining three SNe were spectroscopically confirmed as Type Ia.
- Even stronger constraints once full light curves are considered (Barbary et al. 2010)

Typing by host results

TABLE 2
A PRIORI RATE ESTIMATES FOR EARLY-TYPE SCP SN HOST GALAXIES

Name	log(Mass)	median SFR $M_\odot yr^{-1}$	median $R_{SN\ CC}$ [a] $10^{-3} yr^{-1}$		median $R_{SN\ Ia}$ [a] $10^{-3} yr^{-1}$		P(CC)	Notes
SN SCP05D0	10.9	1.93	0.47	(12.44)	3.11	(4.51)	0.13	s,L
SN SCP05D6	11.4	9.26	0.84	(59.57)	9.20	(17.35)	0.08	L
SN SCP06A4	10.7	1.04	0.13	(6.70)	1.79	(2.87)	0.06	L
SN SCP06C0	11.2	7.99	1.51	(51.37)	8.13	(12.13)	0.15	L
SN SCP06G4	11.2	0.42	0.03	(2.71)	4.78	(9.27)	< 0.01	s,L
SN SCP06H5	11.6	1.16	0.15	(7.46)	12.42	(21.32)	0.01	L
SN SCP06K0	11.4	1.18	0.09	(7.57)	5.09	(14.86)	0.02	L
SN SCP06K18	11.8	0.61	0.05	(3.92)	11.14	(32.58)	< 0.01	
SN SCP06R12	10.4	0.07	< 0.01	(0.44)	0.81	(1.38)	0.01	L
SN SCP06U4	11.1	27.01	6.87	(173.73)	11.94	(17.90)	0.36	s,L

[a] Rates in parentheses are *intrinsic* quantities. Rates not in parentheses are *apparent* and factor in SN detectability.
[s] Spectroscopically confirmed SN Ia.
[L] Light curve shape, color and magnitude consistent with Type Ia (Barbary et al. 2010).

Meyers et al. (submitted)

- Seven of ten z > 0.9 early-type hosted SNe have P(CC) < 10%
- Two of remaining three SNe were spectroscopically confirmed as Type Ia.
- Even stronger constraints once full light curves are considered (Barbary et al. 2010)

Typing by host results

TABLE 2
A PRIORI RATE ESTIMATES FOR EARLY-TYPE SCP SN HOST GALAXIES

Name	log(Mass)	median SFR $M_\odot yr^{-1}$	median $R_{SN\ CC}$ [a] $10^{-3} yr^{-1}$		median $R_{SN\ Ia}$ [a] $10^{-3} yr^{-1}$		P(CC)	Notes
SN SCP05D0	10.9	1.93	0.47	(12.44)	3.11	(4.51)	0.13	s,L
SN SCP05D6	11.4	9.26	0.84	(59.57)	9.20	(17.35)	0.08	L
SN SCP06A4	10.7	1.04	0.13	(6.70)	1.79	(2.87)	0.06	L
SN SCP06C0	11.2	7.99	1.51	(51.37)	8.13	(12.13)	0.15	L
SN SCP06G4	11.2	0.42	0.03	(2.71)	4.78	(9.27)	< 0.01	s,L
SN SCP06H5	11.6	1.16	0.15	(7.46)	12.42	(21.32)	0.01	L
SN SCP06K0	11.4	1.18	0.09	(7.57)	5.09	(14.86)	0.02	L
SN SCP06K18	11.8	0.61	0.05	(3.92)	11.14	(32.58)	< 0.01	
SN SCP06R12	10.4	0.07	< 0.01	(0.44)	0.81	(1.38)	0.01	L
SN SCP06U4	11.1	27.01	6.87	(173.73)	11.94	(17.90)	0.36	s,L

[a] Rates in parentheses are *intrinsic* quantities. Rates not in parentheses are *apparent* and factor in SN detectability.
[s] Spectroscopically confirmed SN Ia.
[L] Light curve shape, color and magnitude consistent with Type Ia (Barbary et al. 2010).

Meyers et al. (submitted)

- Seven of ten z > 0.9 early-type hosted SNe have P(CC) < 10%
- Two of remaining three SNe were spectroscopically confirmed as Type Ia.
- Even stronger constraints once full light curves are considered (Barbary et al. 2010)

Typing by host results

TABLE 2
A PRIORI RATE ESTIMATES FOR EARLY-TYPE SCP SN HOST GALAXIES

Name	log(Mass)	median SFR $M_\odot yr^{-1}$	median $R_{SN\ CC}$ [a] $10^{-3} yr^{-1}$		median $R_{SN\ Ia}$ [a] $10^{-3} yr^{-1}$		P(CC)	Notes
SN SCP05D0	10.9	1.93	0.47	(12.44)	3.11	(4.51)	0.13	s,L
SN SCP05D6	11.4	9.26	0.84	(59.57)	9.20	(17.35)	0.08	L
SN SCP06A4	10.7	1.04	0.13	(6.70)	1.79	(2.87)	0.06	L
SN SCP06C0	11.2	7.99	1.51	(51.37)	8.13	(12.13)	0.15	L
SN SCP06G4	11.2	0.42	0.03	(2.71)	4.78	(9.27)	< 0.01	s,L
SN SCP06H5	11.6	1.16	0.15	(7.46)	12.42	(21.32)	0.01	L
SN SCP06K0	11.4	1.18	0.09	(7.57)	5.09	(14.86)	0.02	L
SN SCP06K18	11.8	0.61	0.05	(3.92)	11.14	(32.58)	< 0.01	
SN SCP06R12	10.4	0.07	< 0.01	(0.44)	0.81	(1.38)	0.01	L
SN SCP06U4	11.1	27.01	6.87	(173.73)	11.94	(17.90)	0.36	s,L

[a] Rates in parentheses are *intrinsic* quantities. Rates not in parentheses are *apparent* and factor in SN detectability.
[s] Spectroscopically confirmed SN Ia.
[L] Light curve shape, color and magnitude consistent with Type Ia (Barbary et al. 2010).

Meyers et al. (submitted)

- Seven of ten z > 0.9 early-type hosted SNe have P(CC) < 10%
- Two of remaining three SNe were spectroscopically confirmed as Type Ia.
- Even stronger constraints once full light curves are considered (Barbary et al. 2010)

Typing by host results

TABLE 2
A PRIORI RATE ESTIMATES FOR EARLY-TYPE SCP SN HOST GALAXIES

Name	log(Mass)	median SFR $M_\odot yr^{-1}$	median $R_{SN\ CC}$ [a] $10^{-3} yr^{-1}$		median $R_{SN\ Ia}$ [a] $10^{-3} yr^{-1}$		P(CC)	Notes
SN SCP05D0	10.9	1.93	0.47	(12.44)	3.11	(4.51)	0.13	s,L
SN SCP05D6	11.4	9.26	0.84	(59.57)	9.20	(17.35)	0.08	L
SN SCP06A4	10.7	1.04	0.13	(6.70)	1.79	(2.87)	0.06	L
SN SCP06C0	11.2	7.99	1.51	(51.37)	8.13	(12.13)	0.15	L
SN SCP06G4	11.2	0.42	0.03	(2.71)	4.78	(9.27)	< 0.01	s,L
SN SCP06H5	11.6	1.16	0.15	(7.46)	12.42	(21.32)	0.01	L
SN SCP06K0	11.4	1.18	0.09	(7.57)	5.09	(14.86)	0.02	L
SN SCP06K18	11.8	0.61	0.05	(3.92)	11.14	(32.58)	< 0.01	
SN SCP06R12	10.4	0.07	< 0.01	(0.44)	0.81	(1.38)	0.01	L
SN SCP06U4	11.1	27.01	6.87	(173.73)	11.94	(17.90)	0.36	s,L

[a] Rates in parentheses are *intrinsic* quantities. Rates not in parentheses are *apparent* and factor in SN detectability.
[s] Spectroscopically confirmed SN Ia.
[L] Light curve shape, color and magnitude consistent with Type Ia (Barbary et al. 2010).

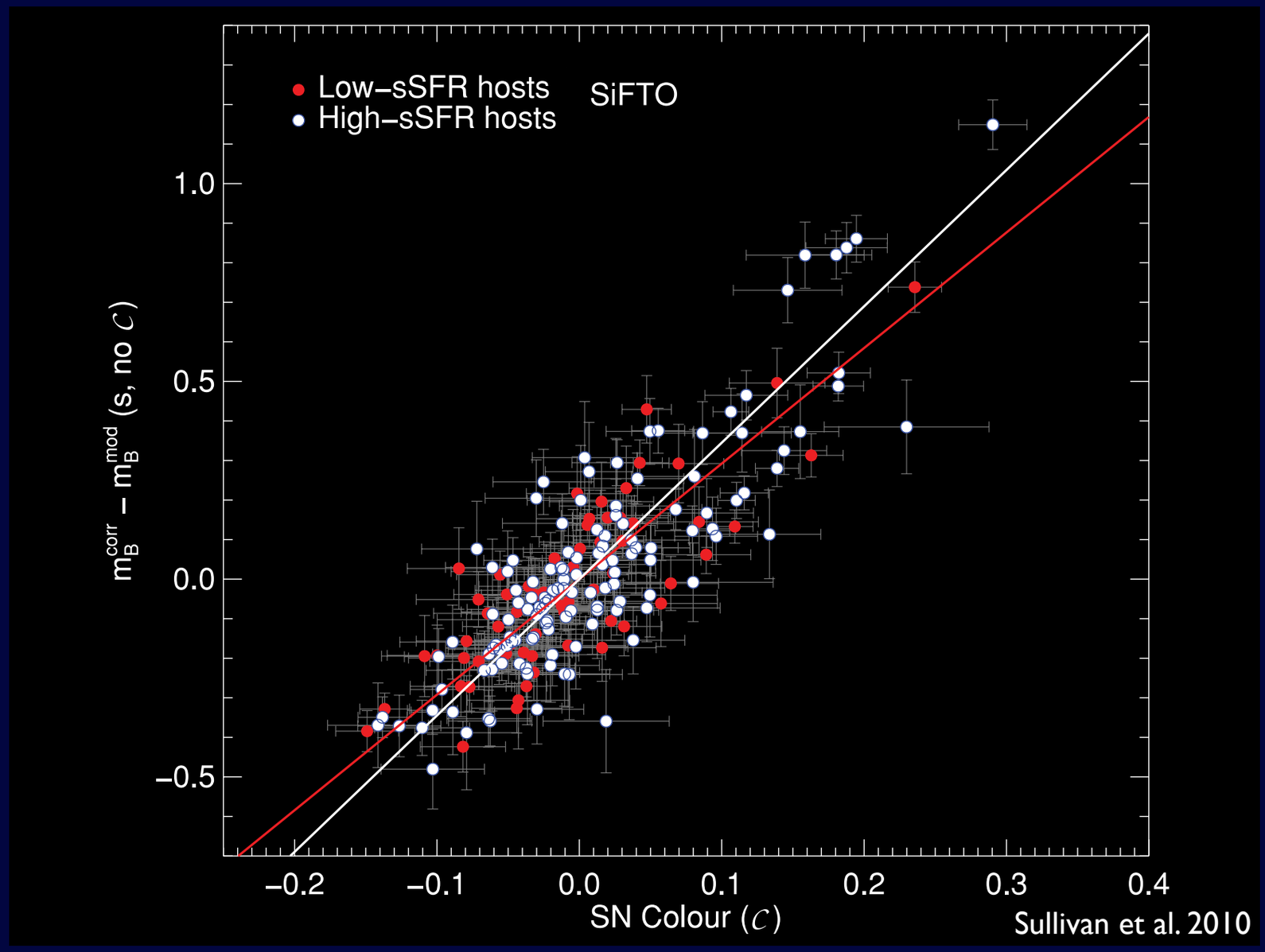
Meyers et al. (submitted)

- Seven of ten z > 0.9 early-type hosted SNe have P(CC) < 10%
- Two of remaining three SNe were spectroscopically confirmed as Type Ia.
- Even stronger constraints once full light curves are considered (Barbary et al. 2010)

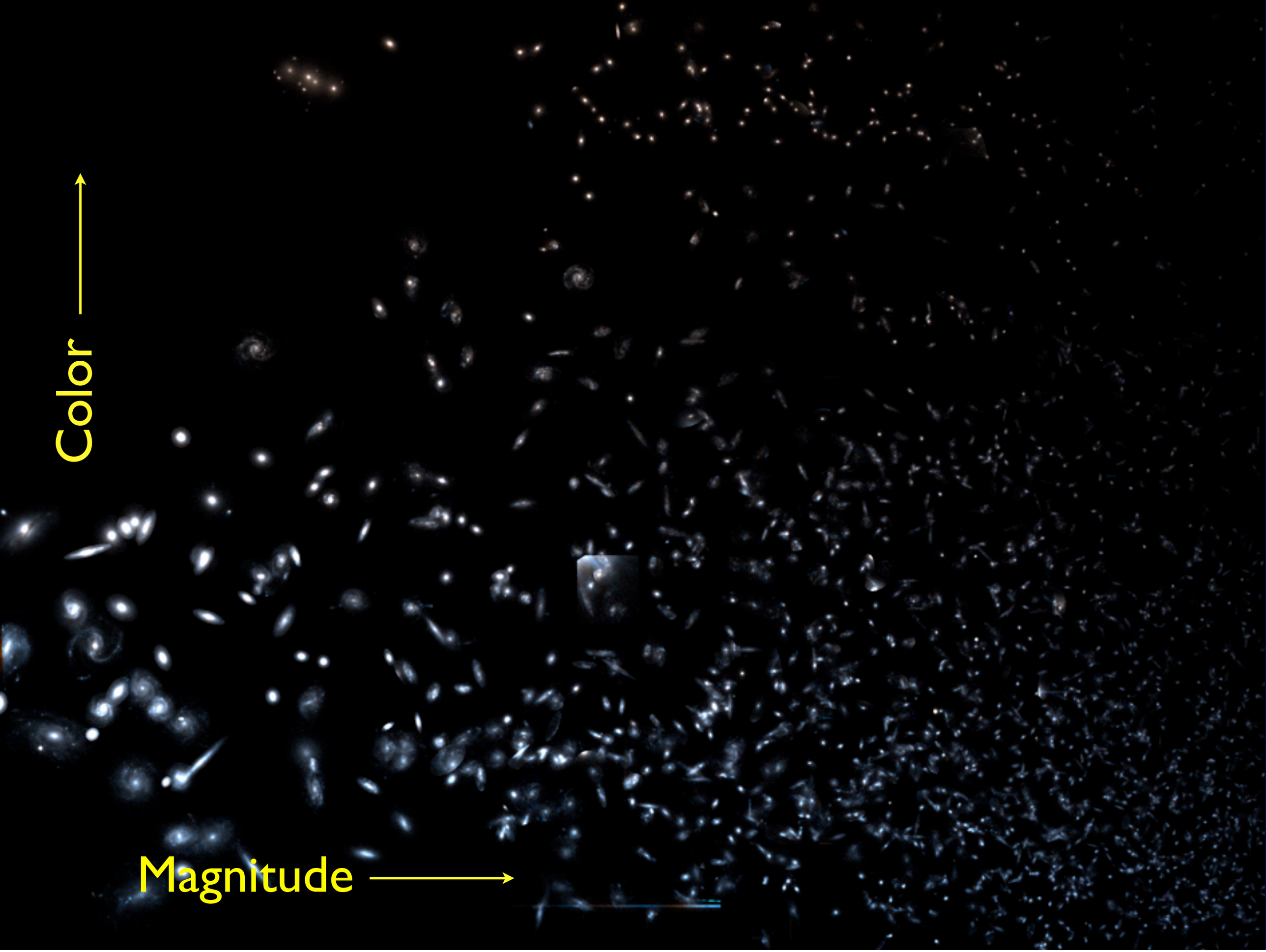
Outline

- SN Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations

SN color-magnitude relation slope depends on host



- The slope $\beta \sim 2.5$
- MW dust $R_B = 4.1$
- Part of relation is intrinsic
- β is larger for High-sSFR hosts
- $\langle\beta\rangle$ may evolve with redshift
- Isolate intrinsic part of β by identifying dust-free hosts

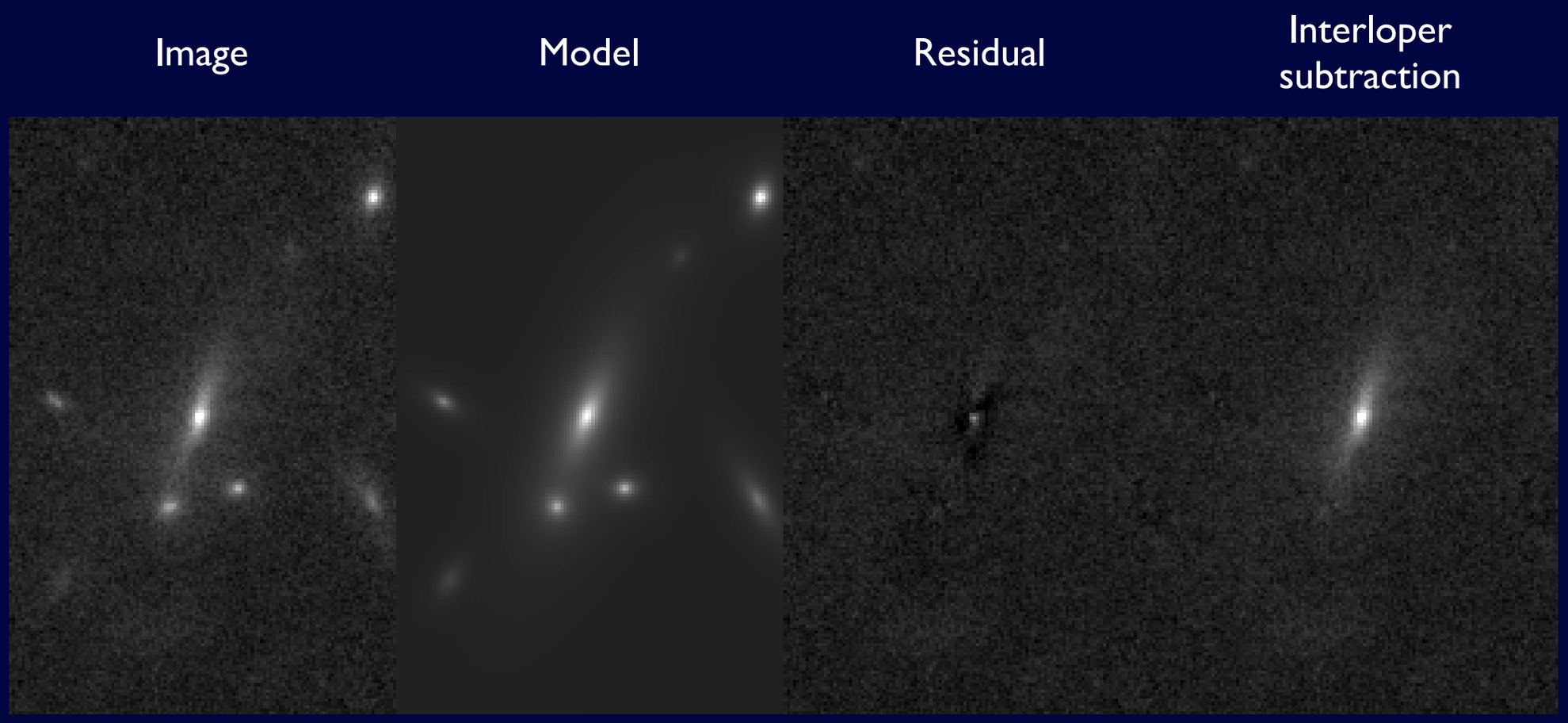

Color
Magnitude

Early-type galaxies criteria

- Morphology: use quantitative morphology parameters
- Photometry: characterize the red sequence
- Spectroscopy: look for signs of star-formation
- We can also apply these criteria to field SN hosts from the GOODS surveys, which used similar i_{775} and z_{850} exposures.

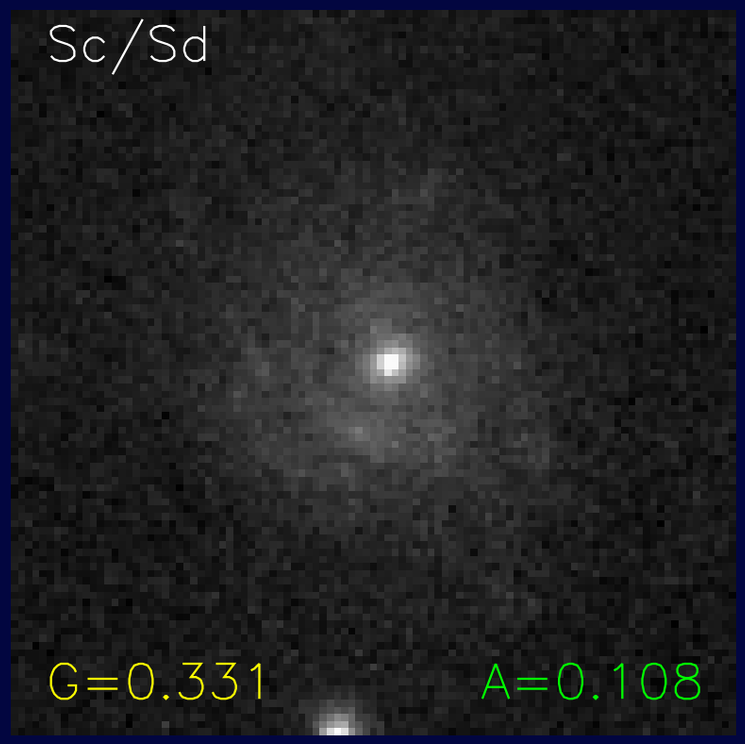
Use GALFIT to measure galaxy magnitudes and colors

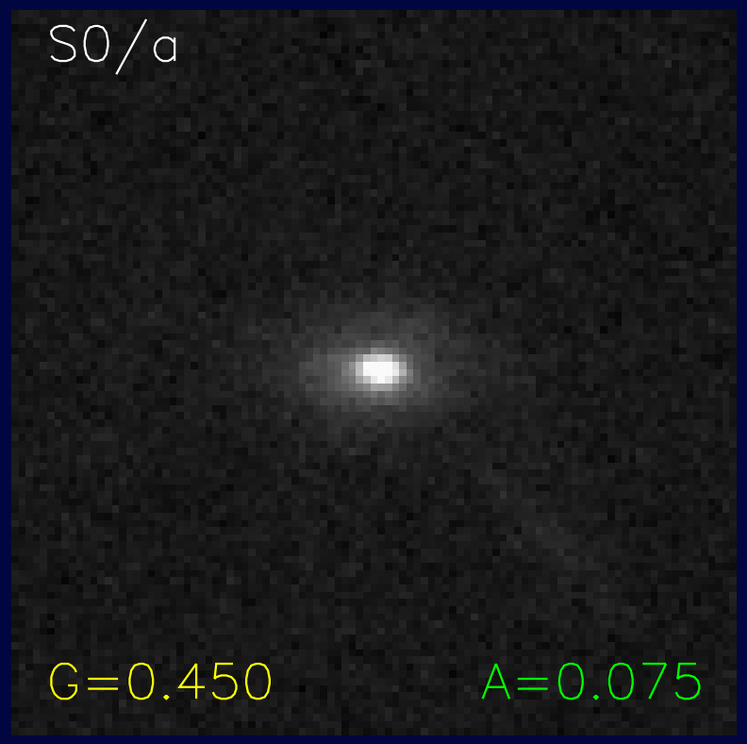
- Simultaneously fit Sersic profiles to really close neighbors
- Mask out sorta close neighbors
- Measure z_{850}, R_e and generate interloper subtracted images



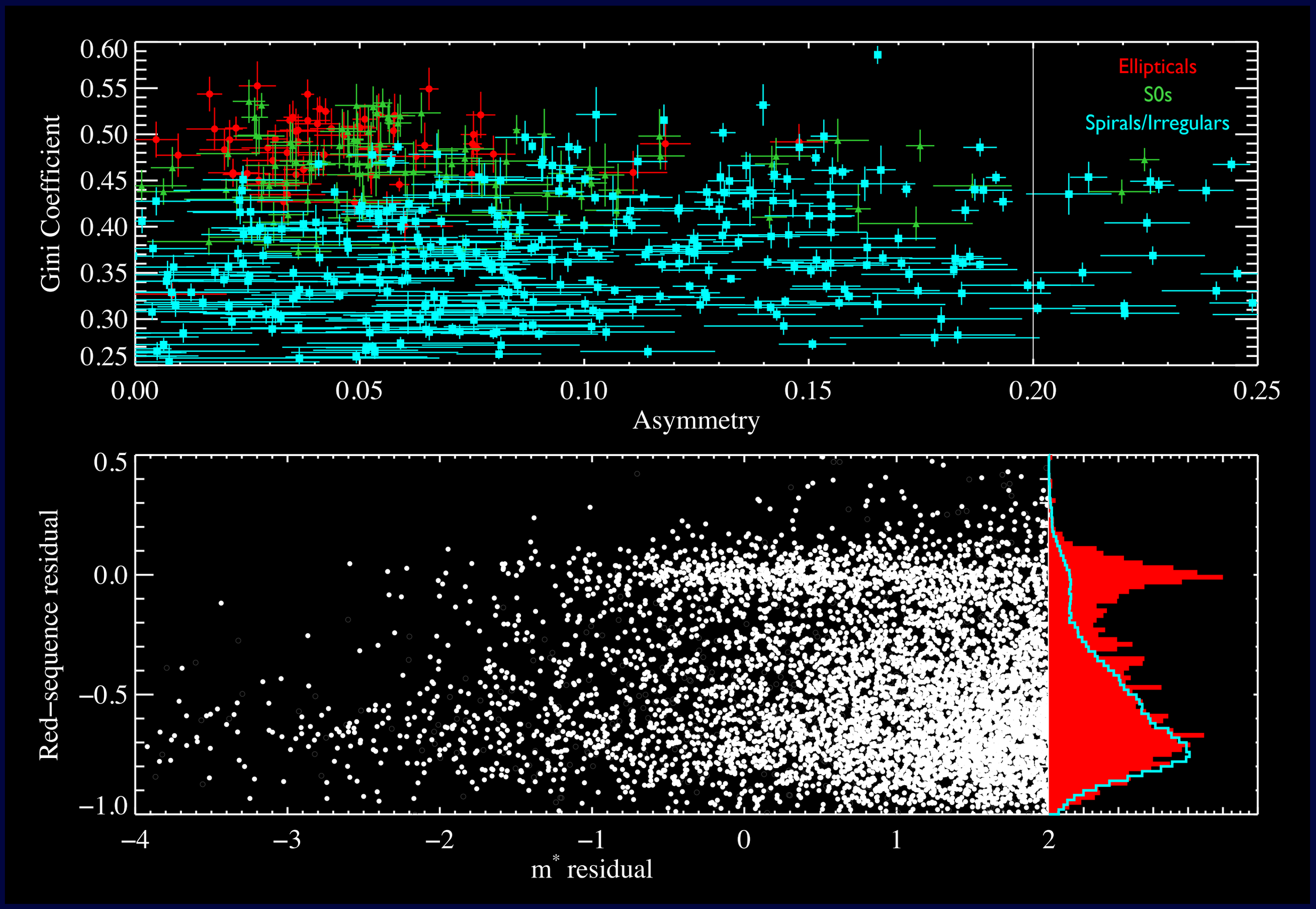
Quantitative Morphology

- The Gini coefficient measures the inequality of a distribution; G=0 is communism, G=1 is monarchy
- Asymmetry index measures the self-similarity of galaxies under 180-degree rotation.

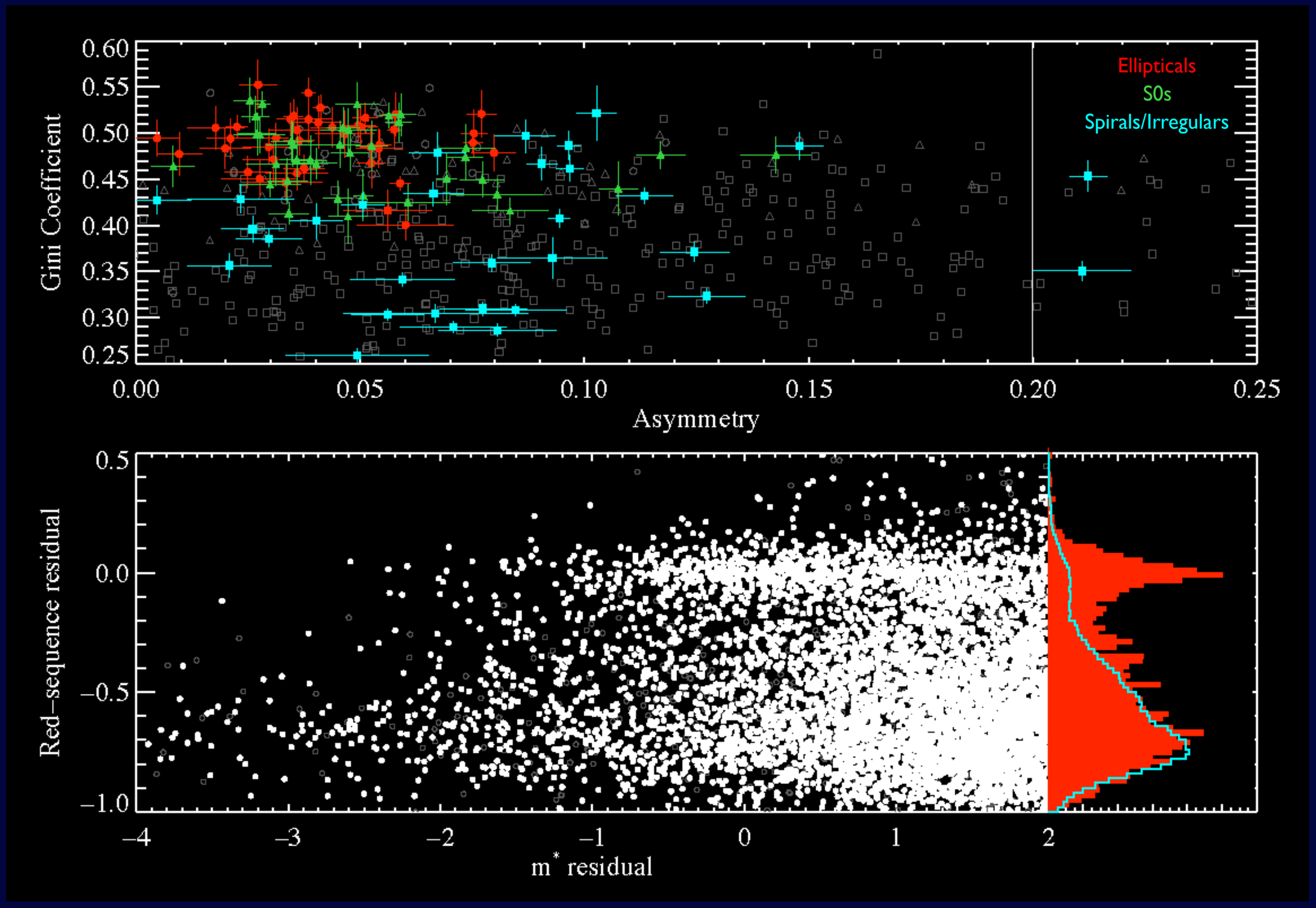




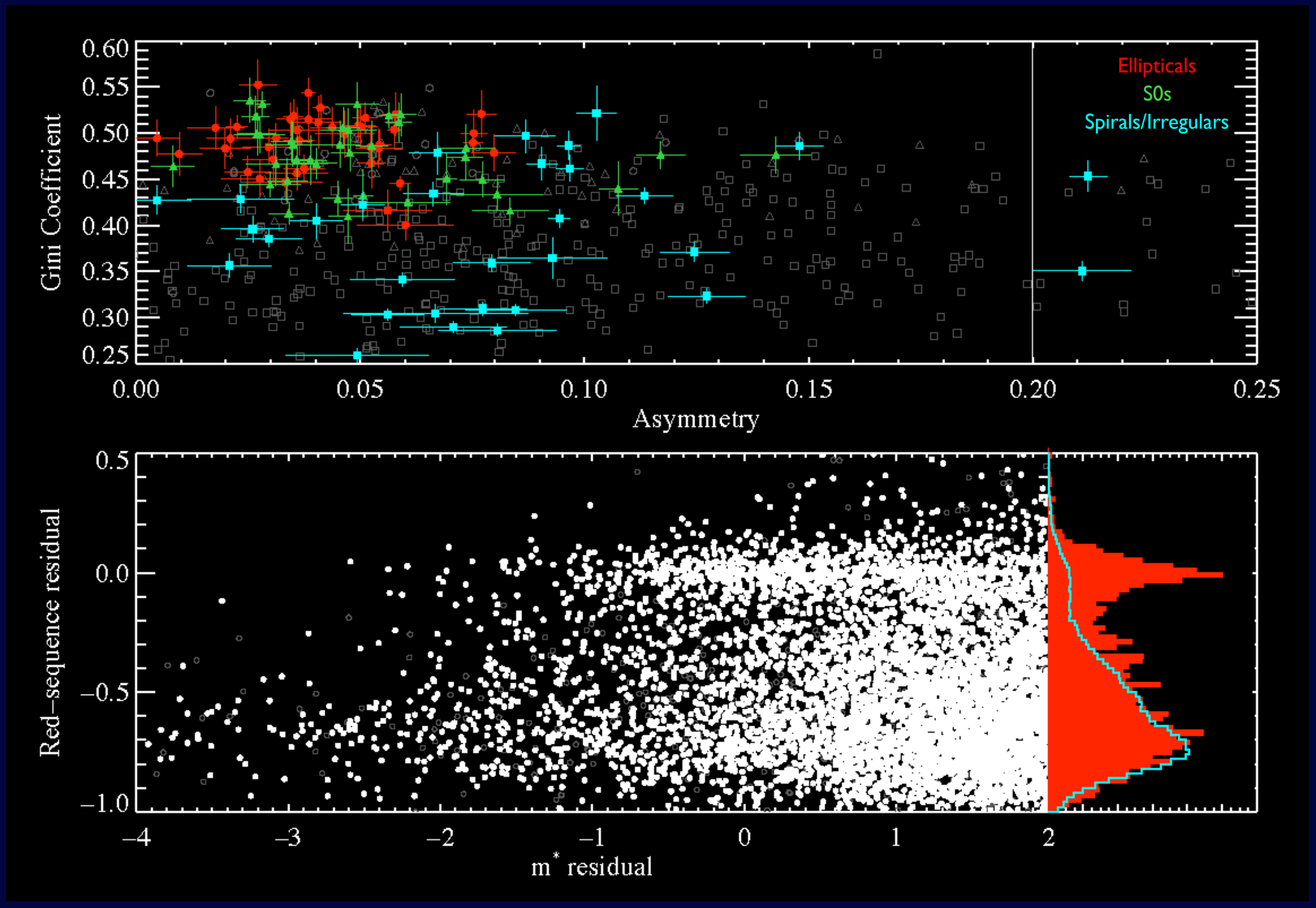
Choosing morphology cuts to enhance the red sequence



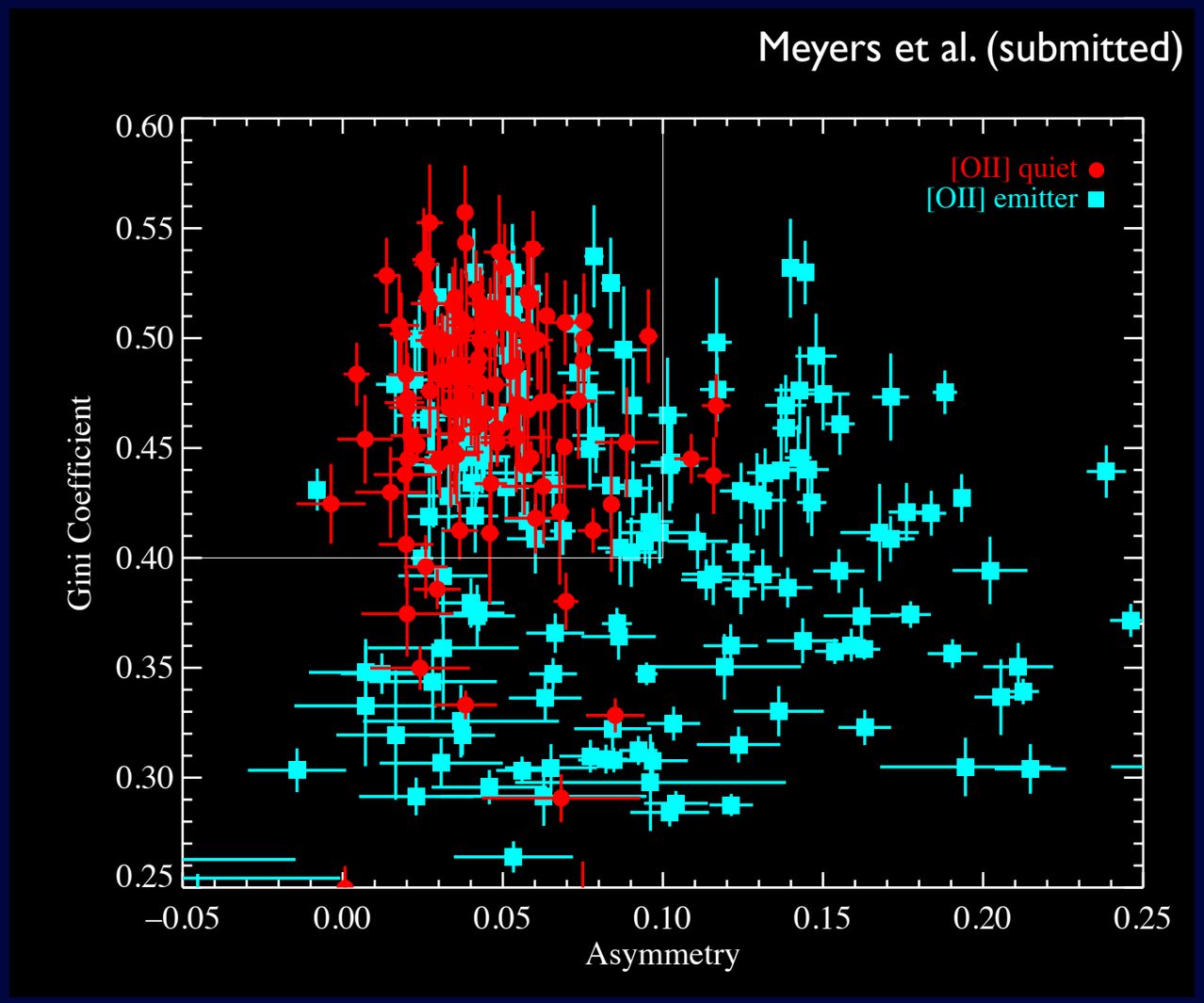
Choosing morphology cuts to enhance the red sequence

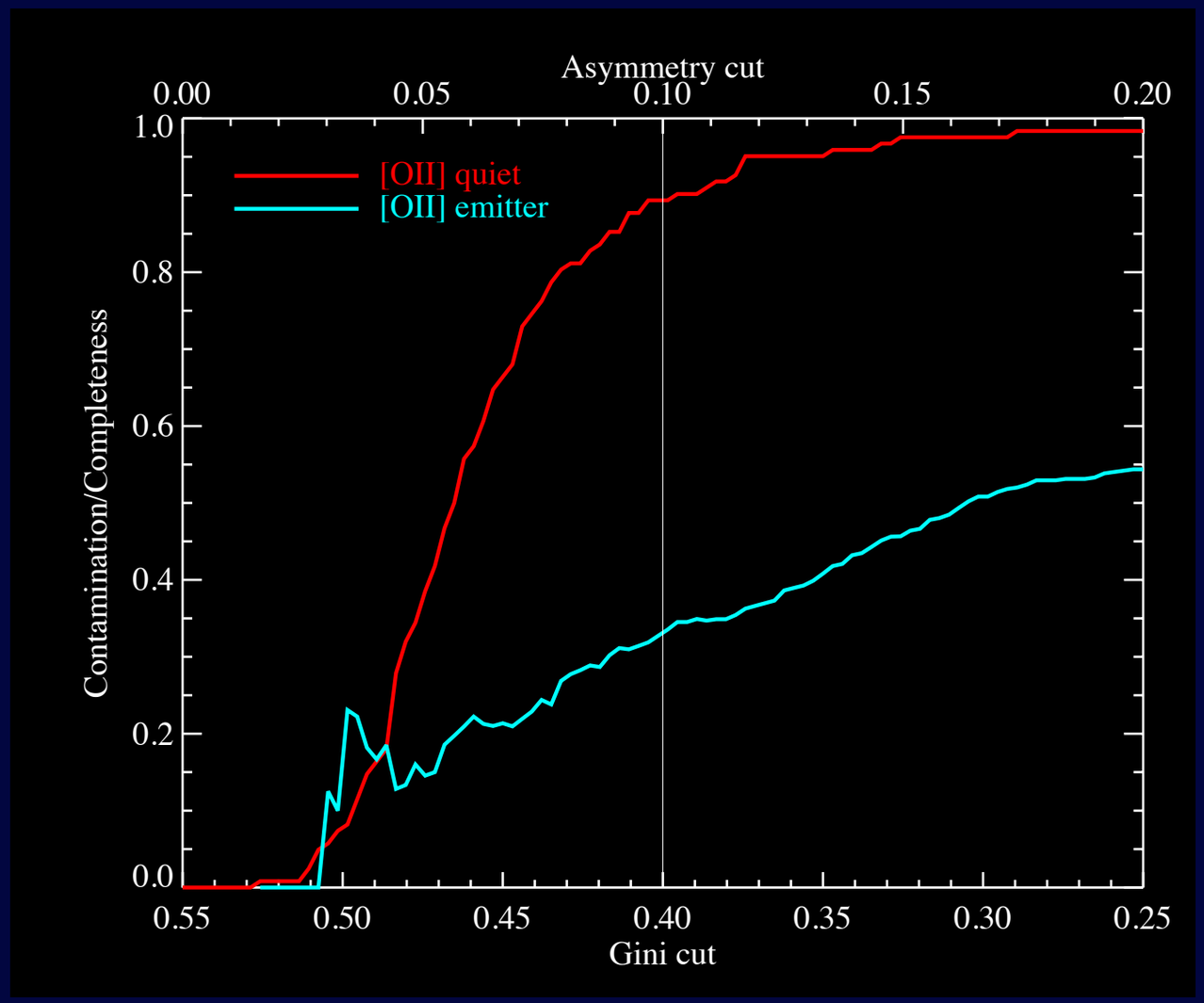


Choosing morphology cuts to enhance the red sequence



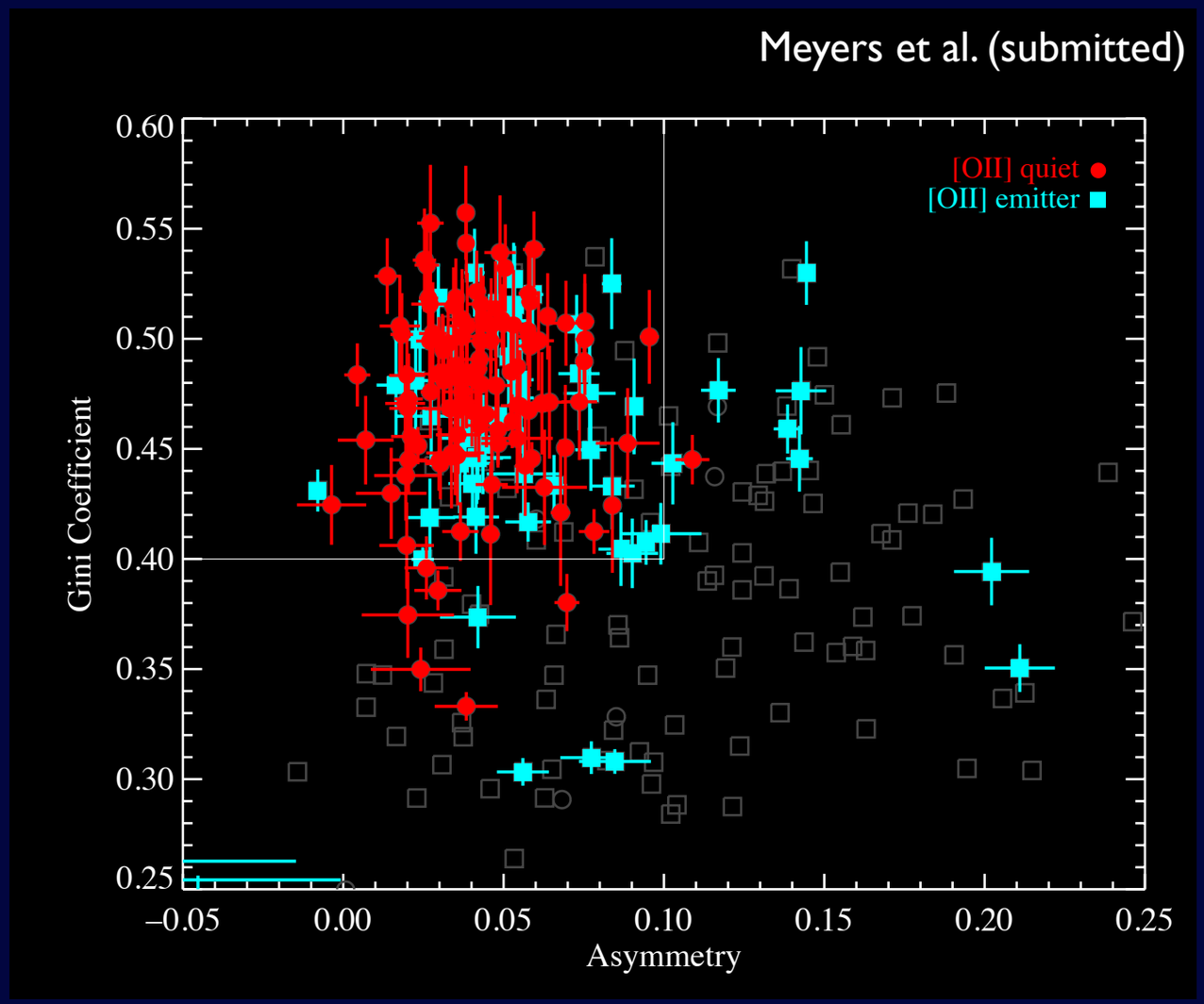
[OII] quiet galaxies are morphologically early-type

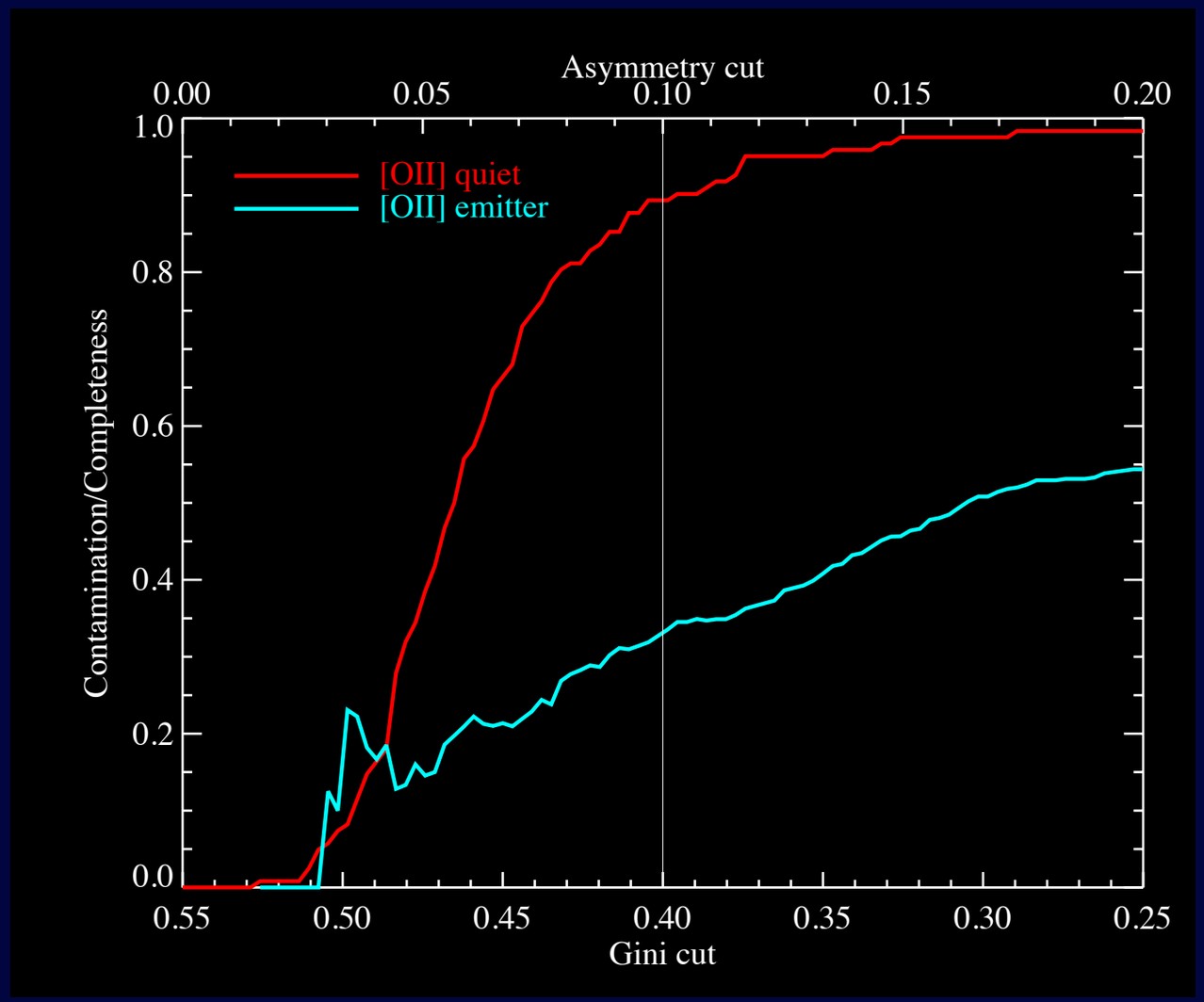




- [OII] quiet means the equivalent width is greater than -5Å.
- [OII] emitter means the equivalent width is less than -5Å.
- Only 9% of red, [OII]-emitting galaxies show star-forming line ratios (Yan et al. 2006)

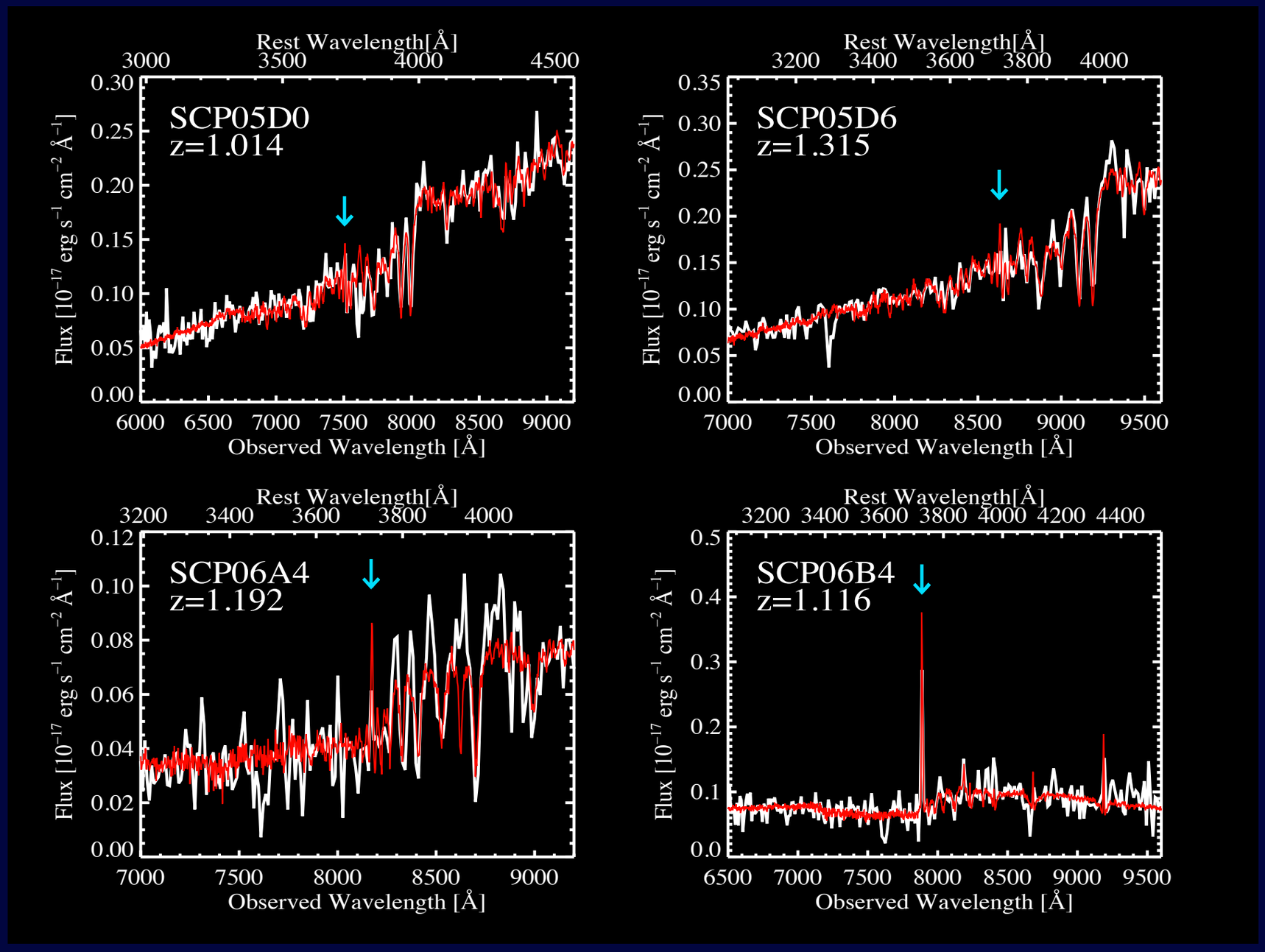
[OII] quiet galaxies are morphologically early-type





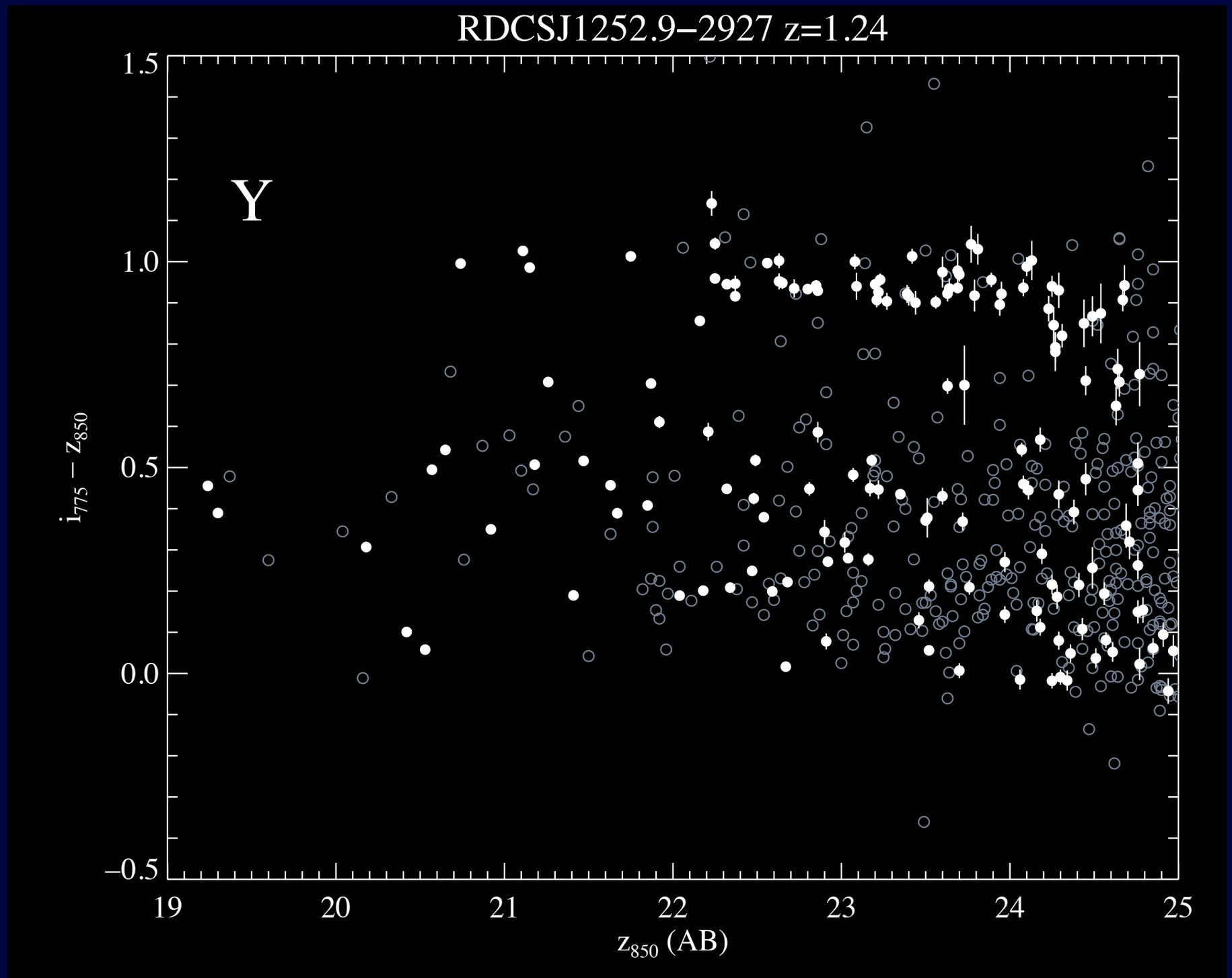
- [OII] quiet means the equivalent width is greater than -5Å.
- [OII] emitter means the equivalent width is less than -5Å.
- Only 9% of red, [OII]-emitting galaxies show star-forming line ratios (Yan et al. 2006)

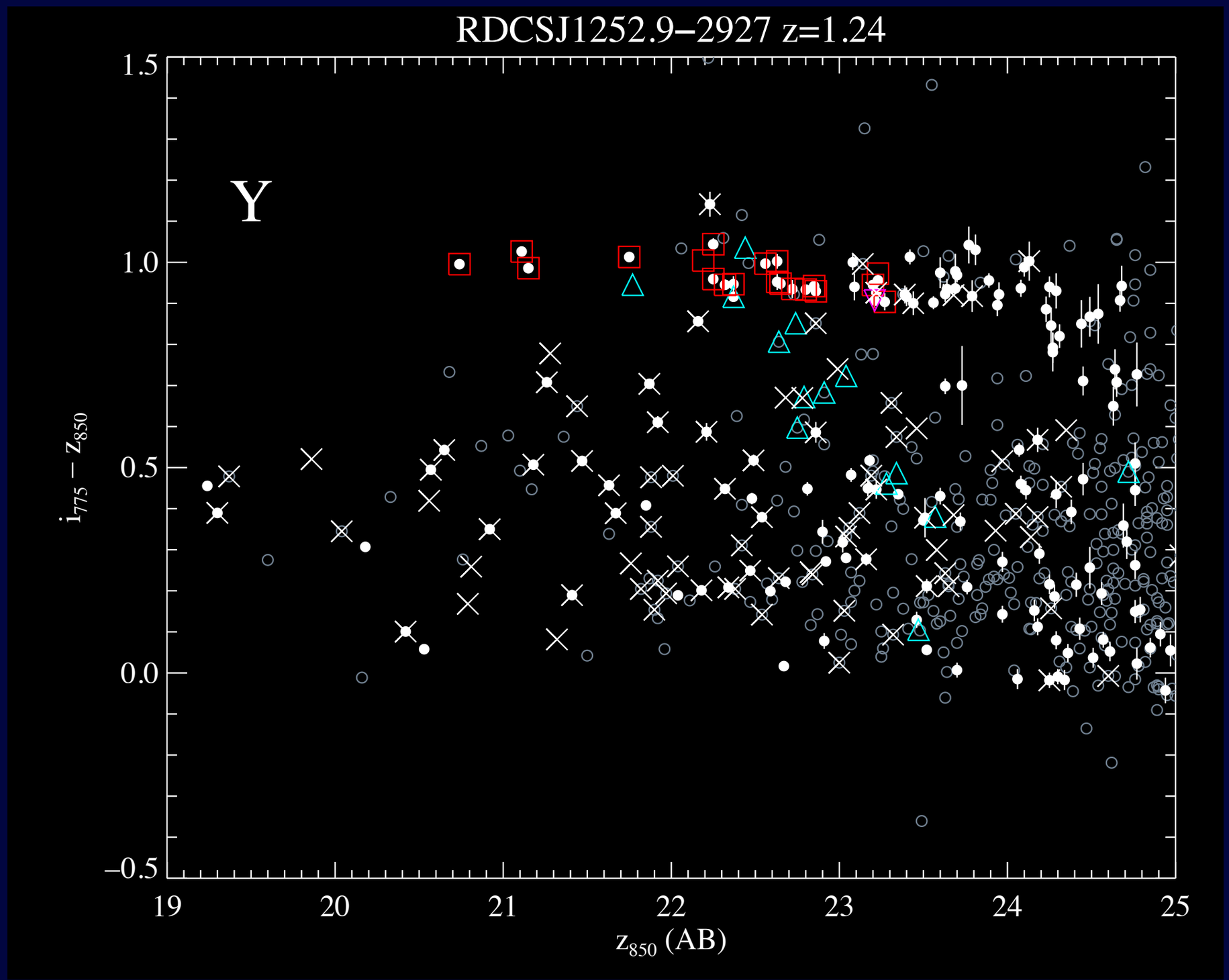
SCP SN Host Spectroscopy

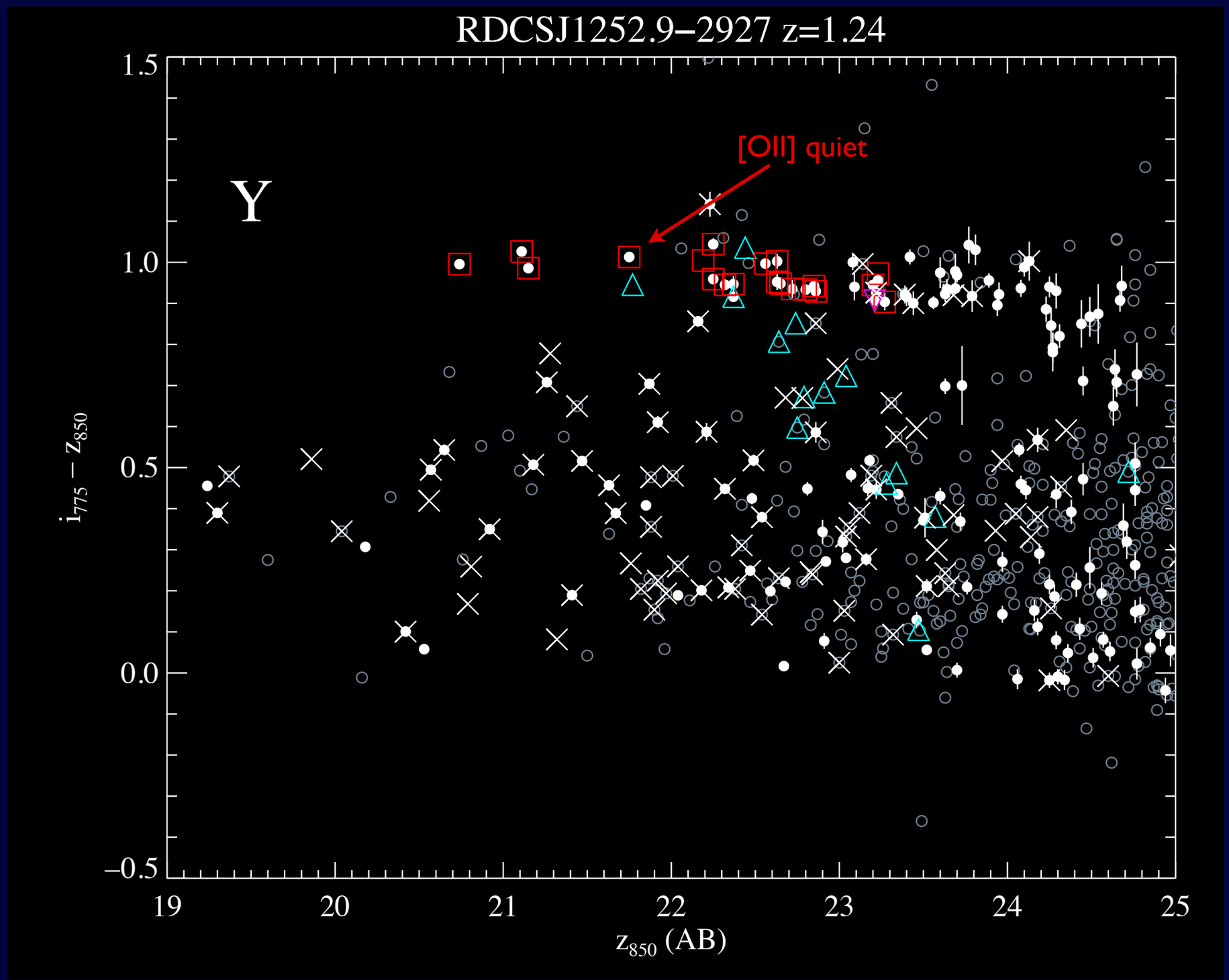


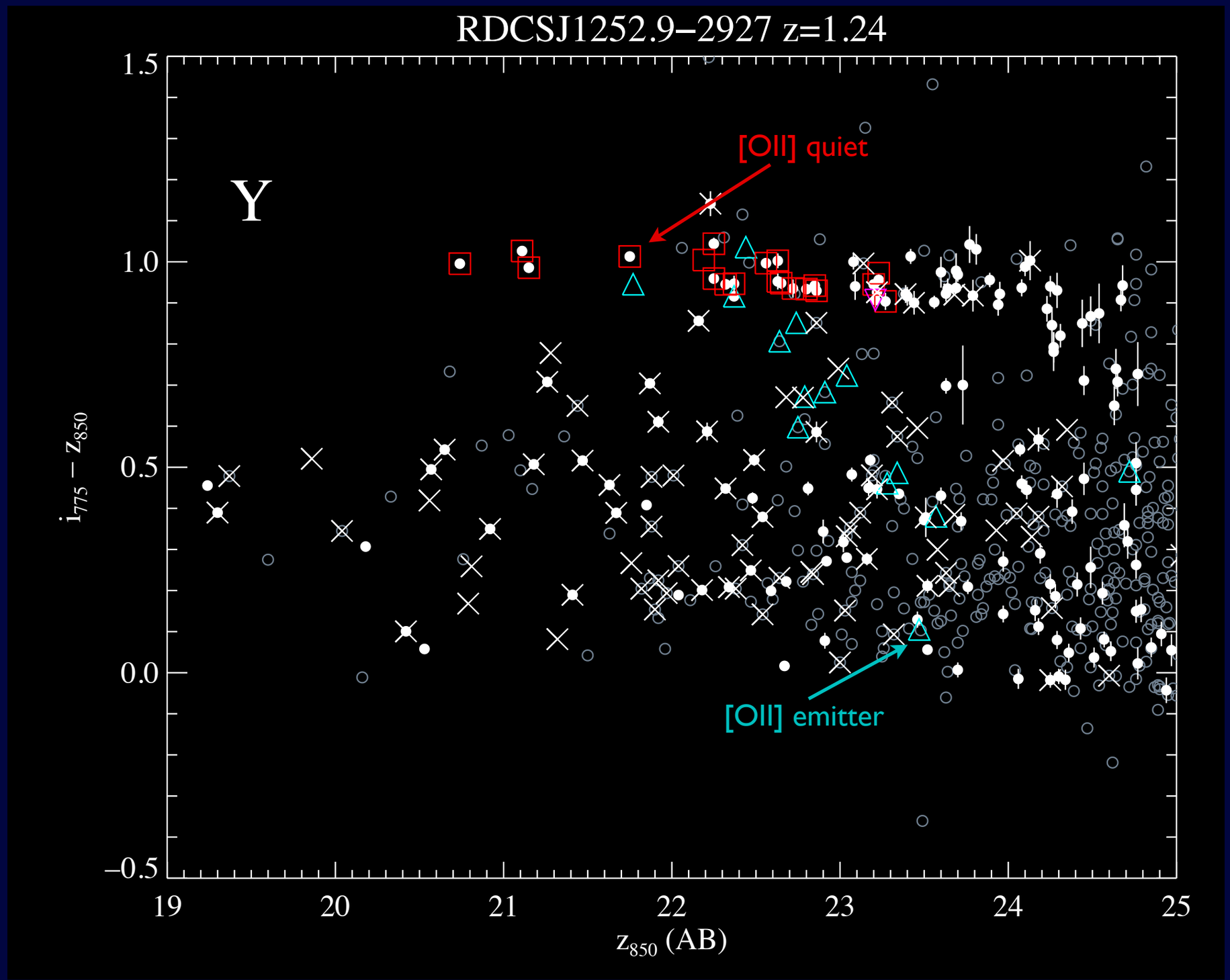
- White = data
- Red = model used to fit redshift
- Blue arrow = [OII] location

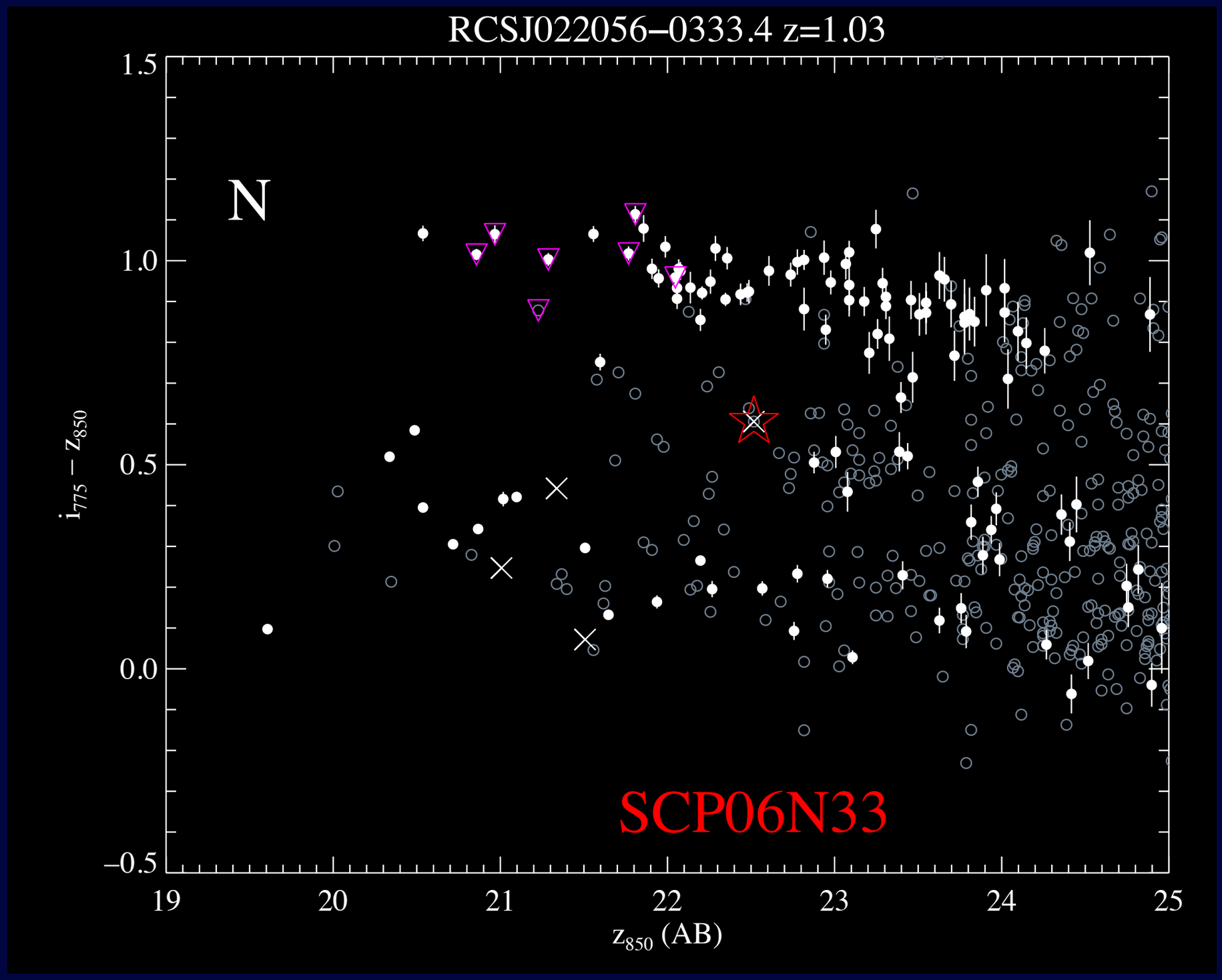
Meyers et al. (submitted)

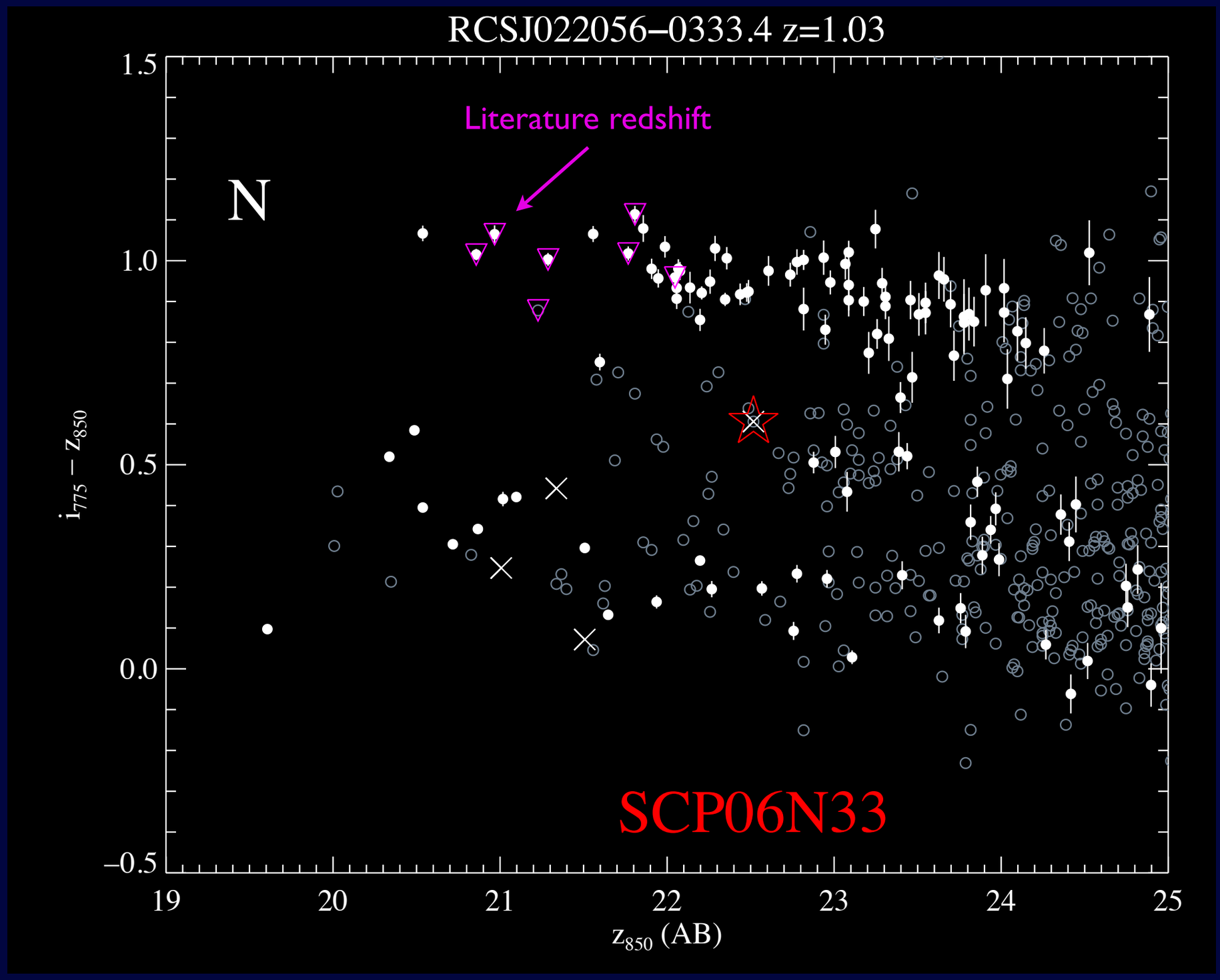

RDCSJ1252.9−2927 z=1.24
Y
1.5
1.0
0.5
0.0
−0.5
$i_{775} - z_{850}$
19
20
21
22
23
24
25
z_{850} (AB)

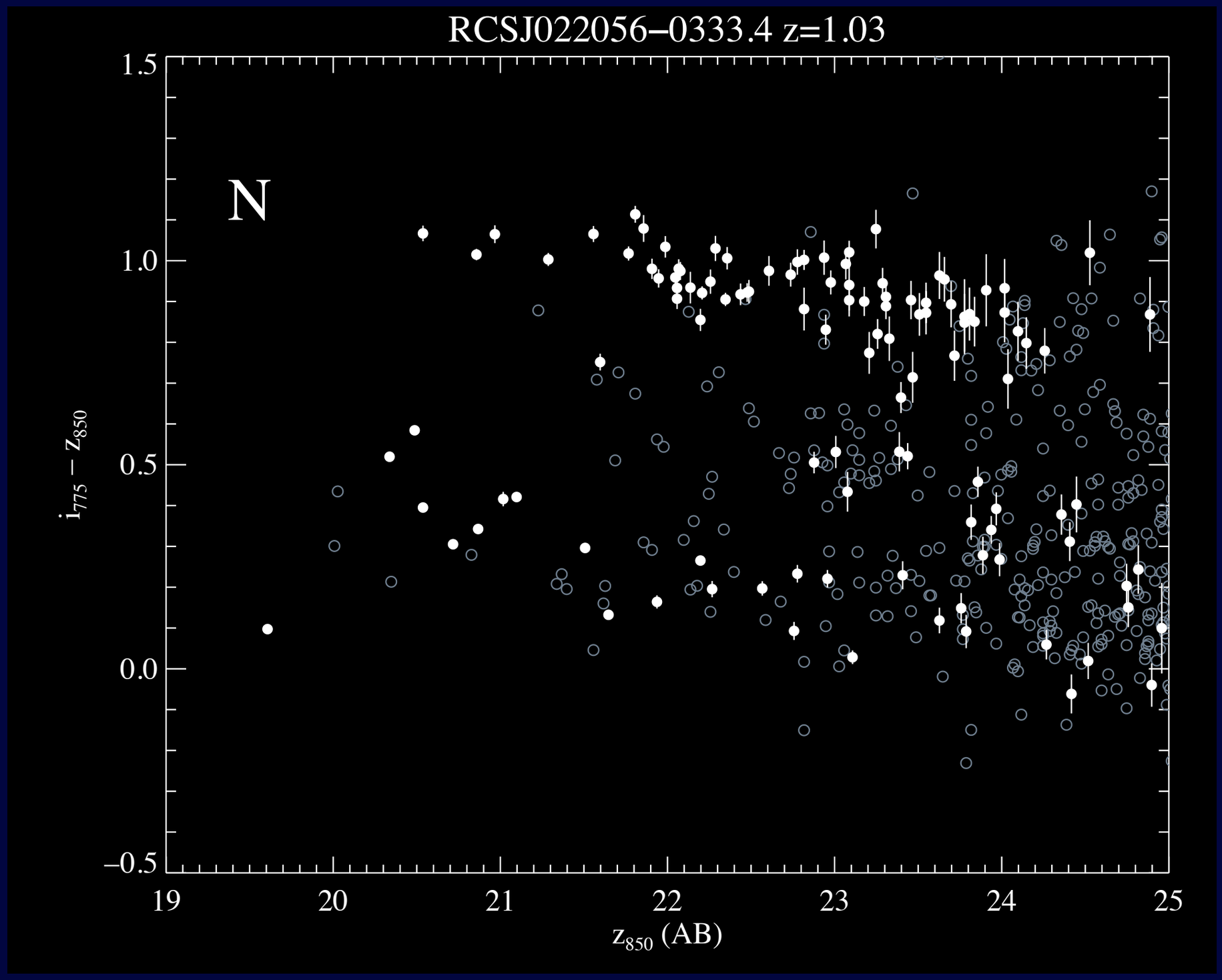

RDCSJ1252.9−2927 z=1.24
Y
1.5
1.0
0.5
0.0
−0.5
19
20
21
22
23
24
25
$i_{775} - z_{850}$
z_{850} (AB)

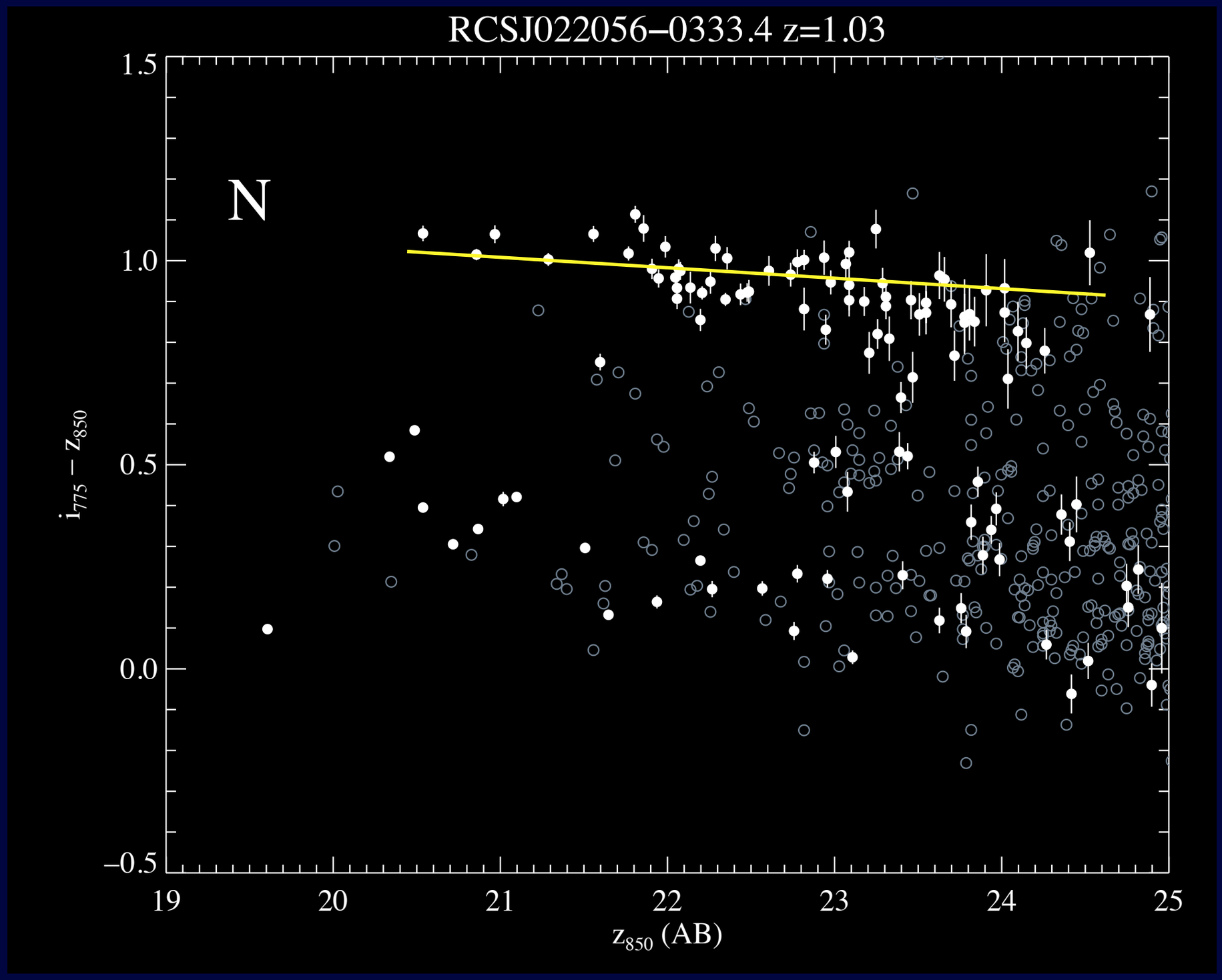

RDCSJ1252.9−2927 z=1.24
Y
[OII] quiet
$i_{775} - z_{850}$
z_{850} (AB)
1.5
1.0
0.5
0.0
−0.5
19
20
21
22
23
24
25

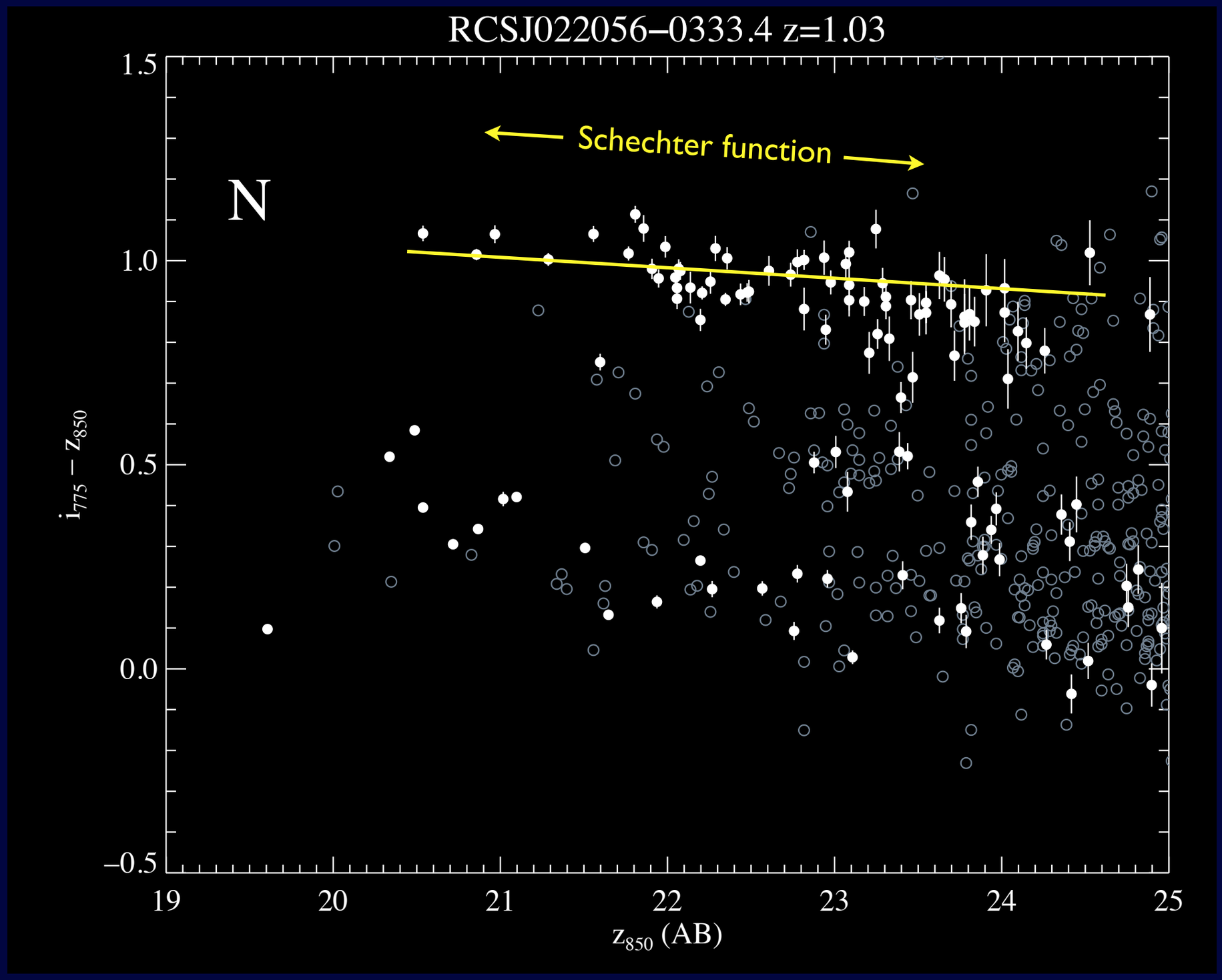

RDCSJ1252.9−2927 z=1.24
Y
[OII] quiet
[OII] emitter
1.5
1.0
0.5
0.0
−0.5
19
20
21
22
23
24
25
$i_{775} - z_{850}$
z_{850} (AB)

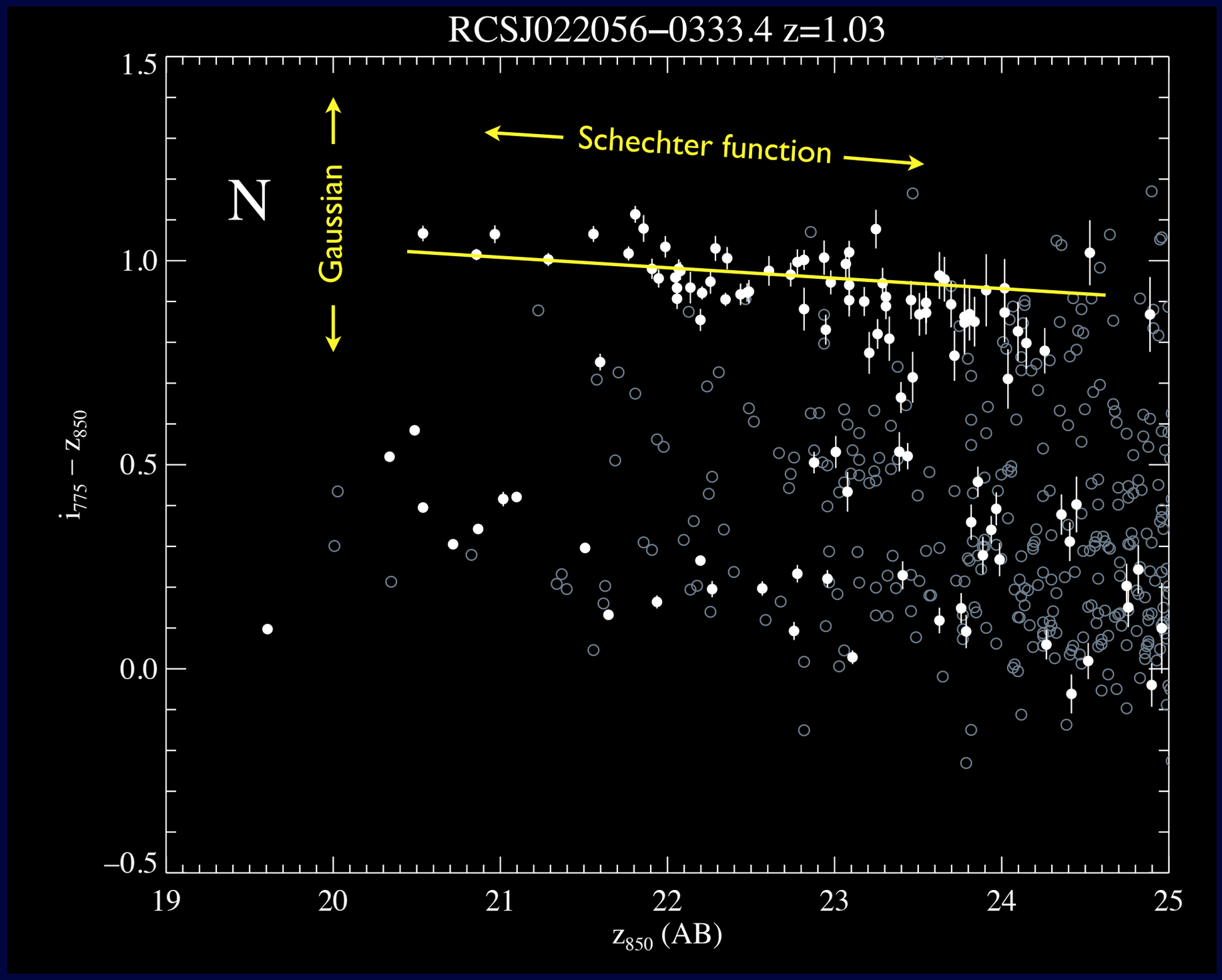

RCSJ022056–0333.4 z=1.03
N
SCP06N33
1.5
1.0
0.5
0.0
–0.5
19
20
21
22
23
24
25
$i_{775} - z_{850}$
z_{850} (AB)

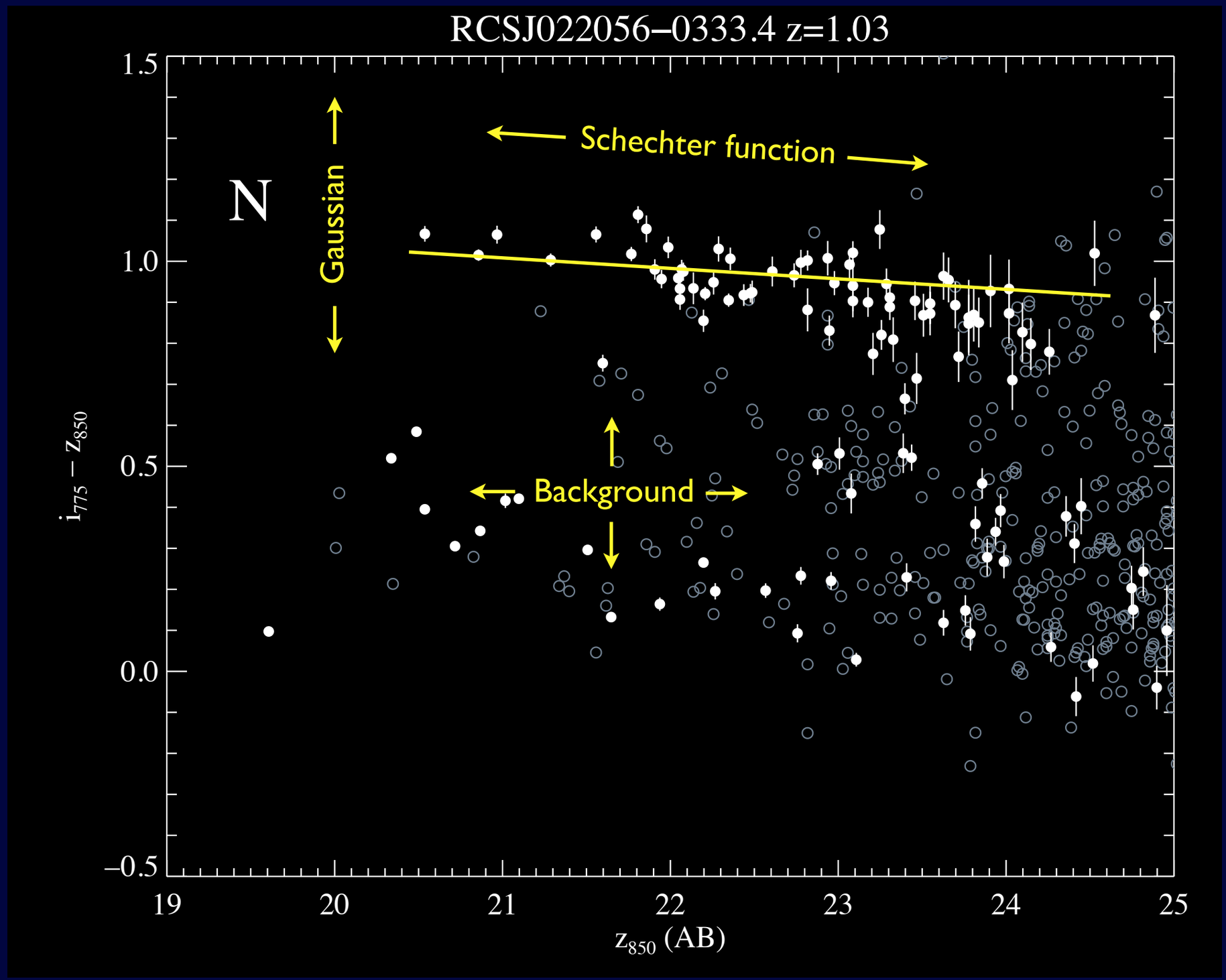

RCSJ022056–0333.4 z=1.03
Literature redshift
N
SCP06N33
$i_{775} - z_{850}$
z_{850} (AB)
1.5
1.0
0.5
0.0
–0.5
19
20
21
22
23
24
25

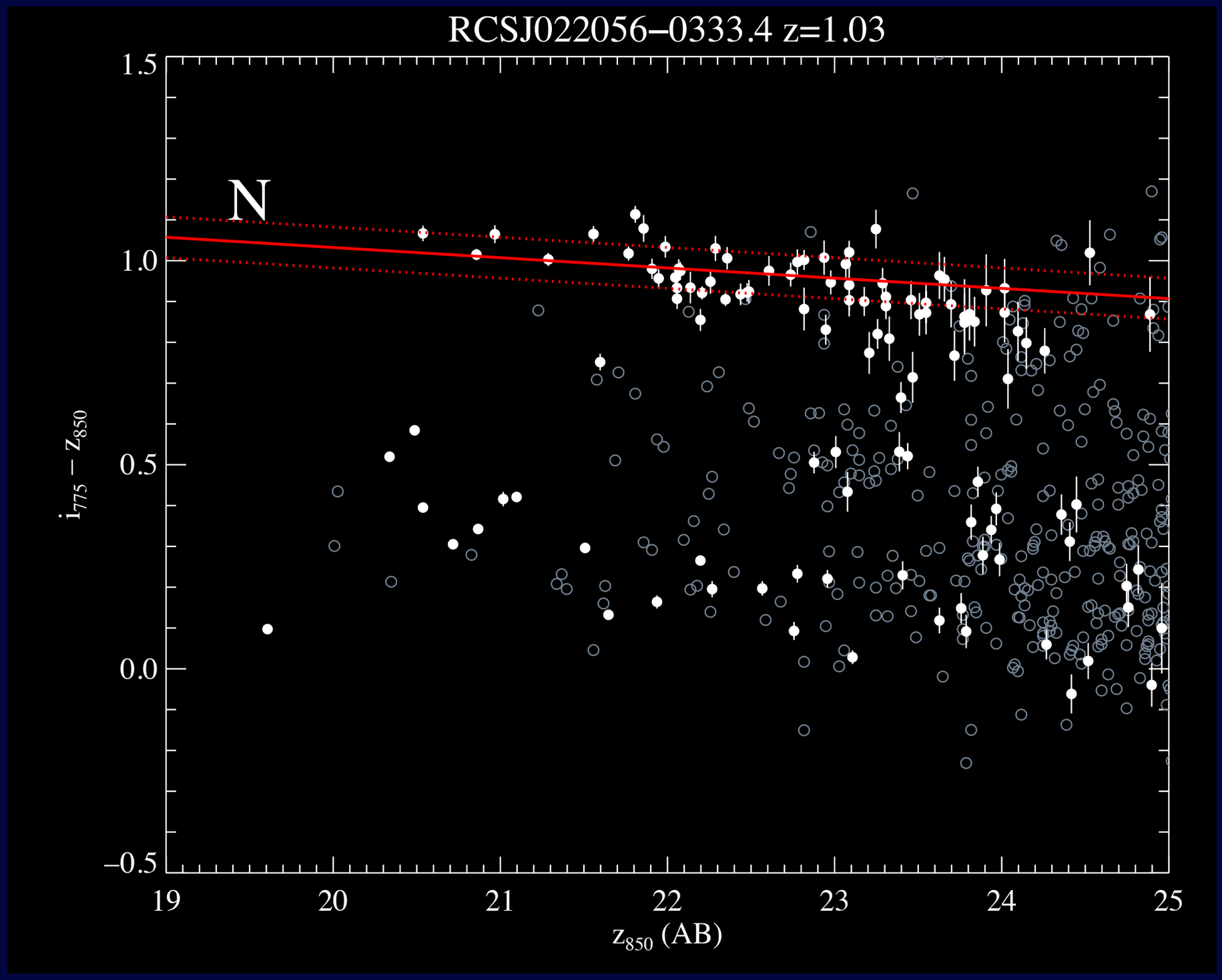

RCSJ022056–0333.4 z=1.03
N
1.5
1.0
0.5
0.0
–0.5
$i_{775} - z_{850}$
19
20
21
22
23
24
25
z_{850} (AB)


RCSJ022056–0333.4 z=1.03
N
1.5
1.0
0.5
0.0
–0.5
$i_{775} - z_{850}$
19
20
21
22
23
24
25
z_{850} (AB)


RCSJ022056–0333.4 z=1.03
Schechter function
N
$i_{775} - z_{850}$
1.5
1.0
0.5
0.0
–0.5
19
20
21
22
23
24
25
z_{850} (AB)


RCSJ022056–0333.4 z=1.03
N
Gaussian
Schechter function
$i_{775} - z_{850}$
z_{850} (AB)
1.5
1.0
0.5
0.0
–0.5
19
20
21
22
23
24
25

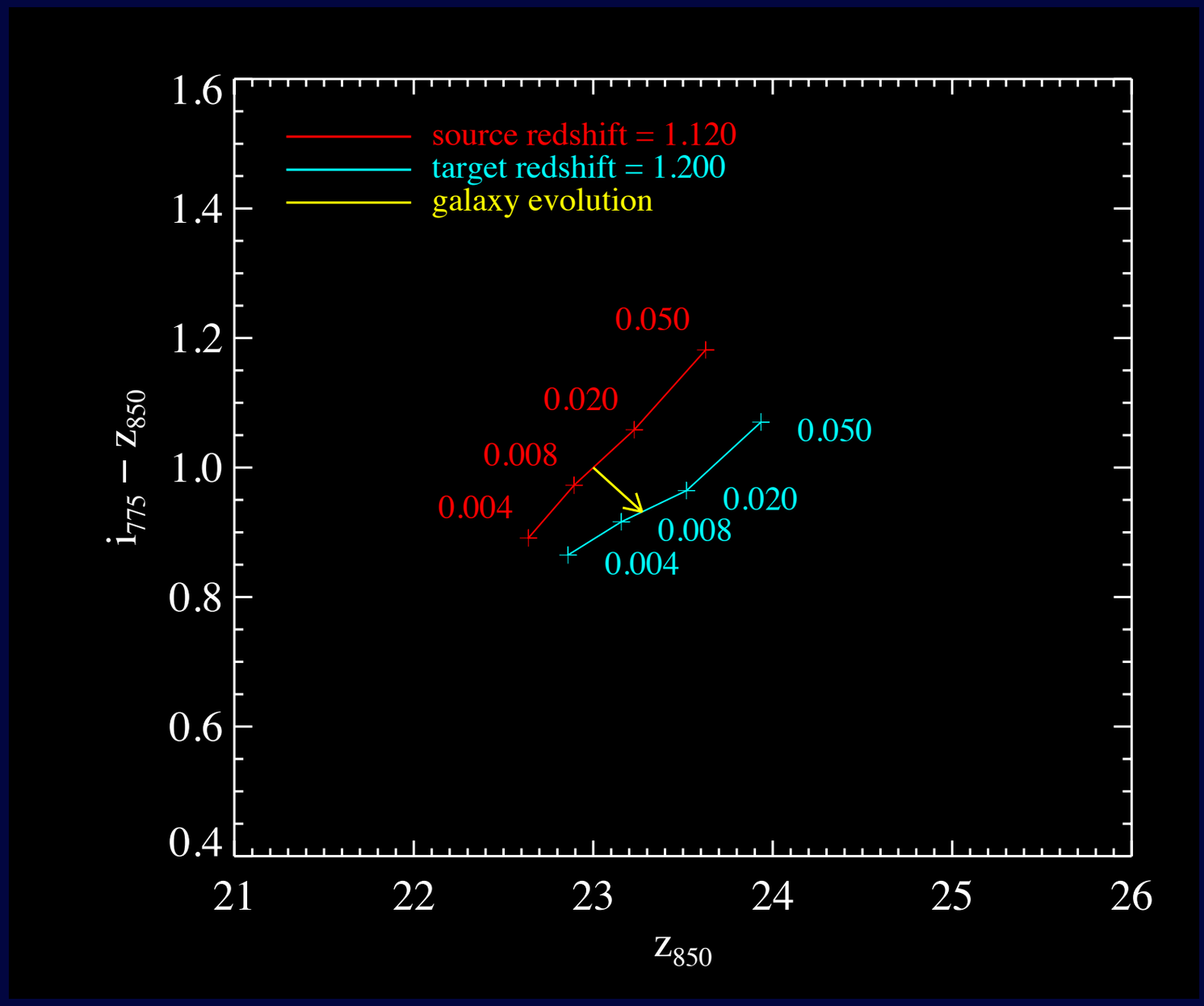

RCSJ022056–0333.4 z=1.03
N
Gaussian
Schechter function
Background
$i_{775} - z_{850}$
z_{850} (AB)
1.5
1.0
0.5
0.0
–0.5
19
20
21
22
23
24
25


RCSJ022056–0333.4 z=1.03
N
1.5
1.0
0.5
0.0
–0.5
$i_{775} - z_{850}$
19
20
21
22
23
24
25
z_{850} (AB)

Compare field host photometry with composite red sequence

Use information from all spectroscopically confirmed red-sequence members to form a composite red sequence:

- fit Bruzual and Charlot 2003 single stellar population model
- assume $z_{form} = 3.0$
- k-correction
- evolution correction



$$F_\lambda = \frac{M_{gal}}{M_\odot} \frac{BC03_\lambda(T(z), Z, z)}{D_L(z)^2}$$

The Composite Red Sequence

- Assign a Gaussian weight to k+e corrected galaxies:

$$w \propto \exp\left(-\frac{(z - z_{targ})^2}{2 \cdot 0.15^2}\right)$$

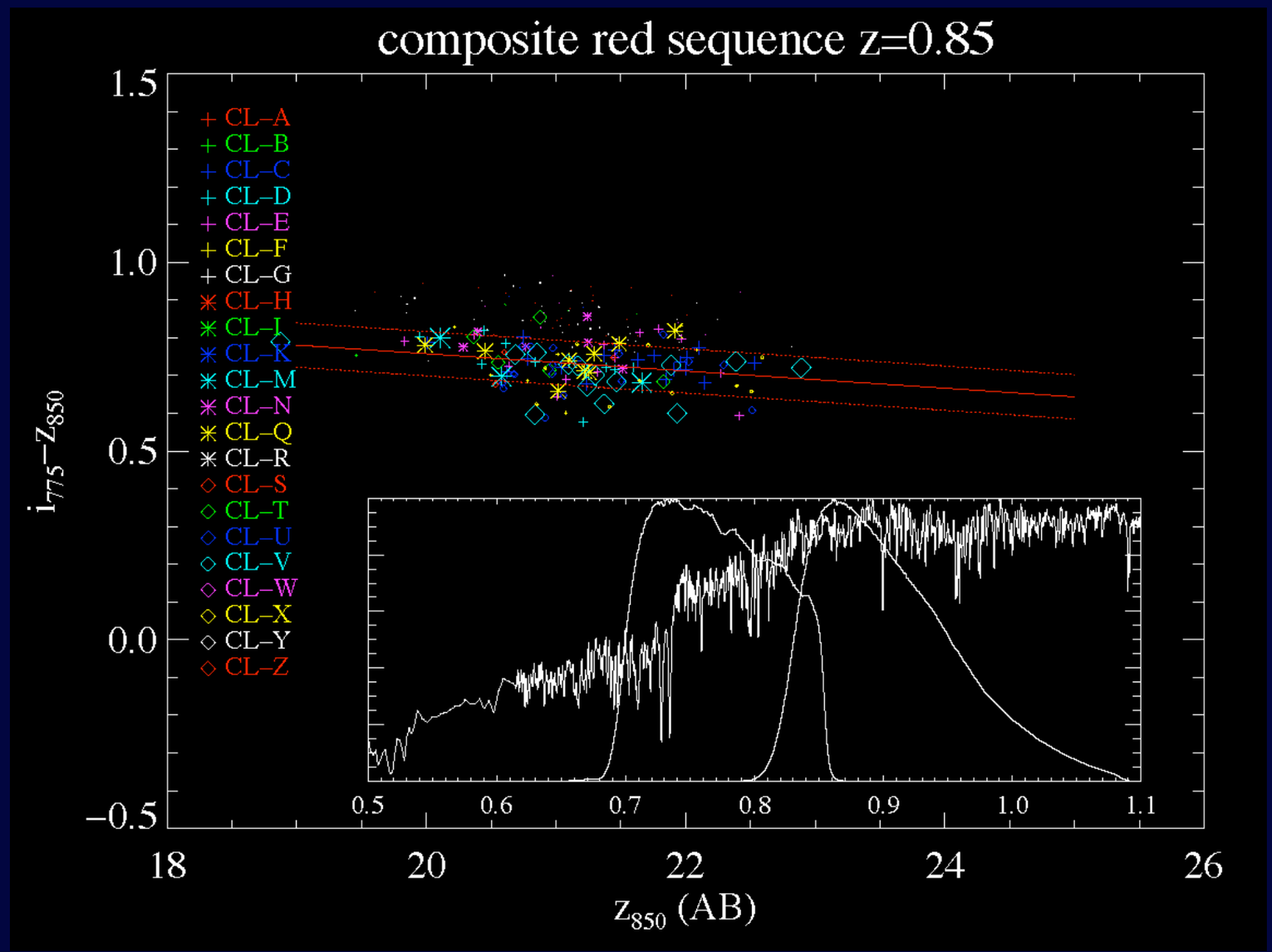
- Plot symbol size is proportional to the weight

The Composite Red Sequence

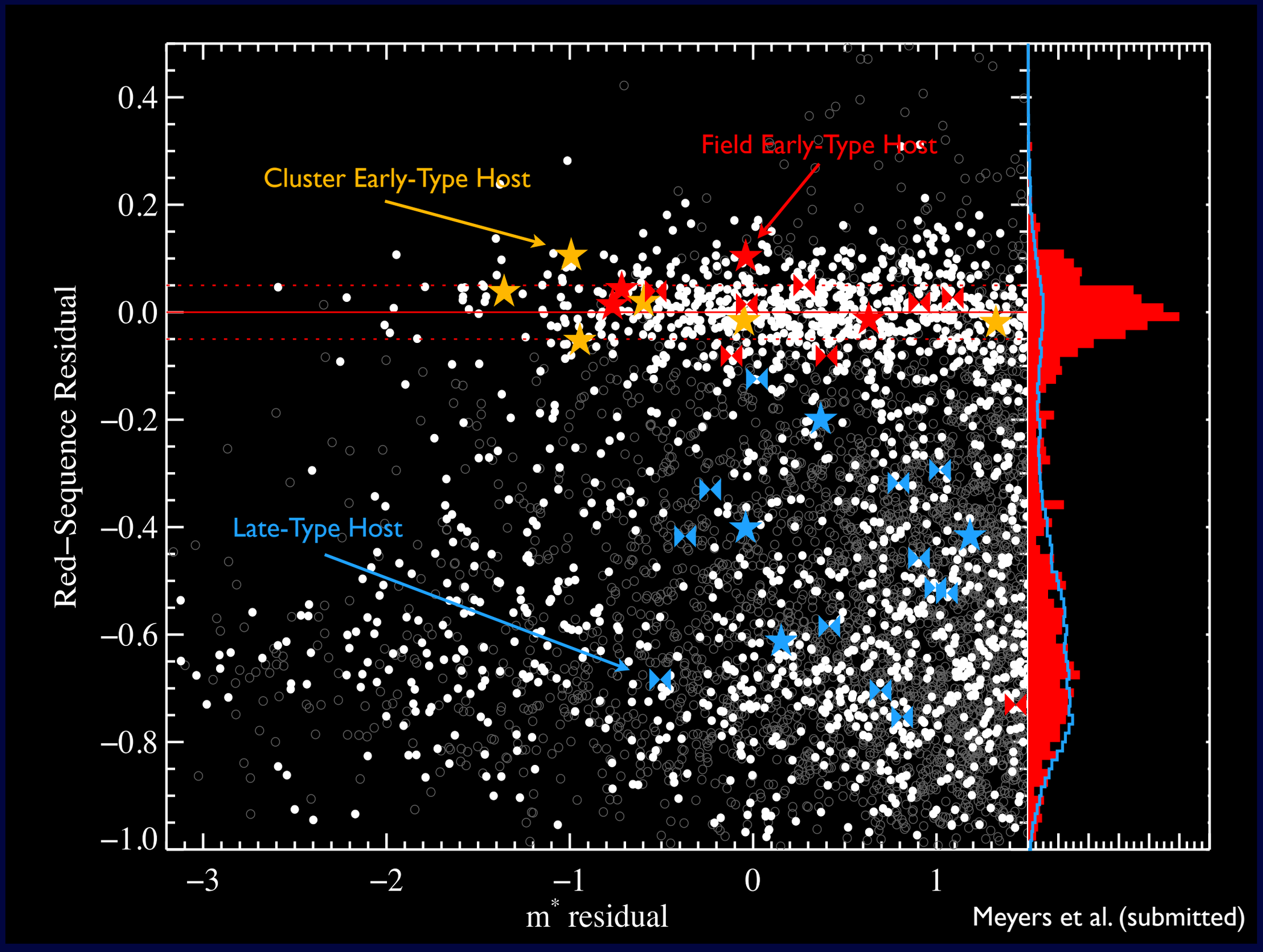
- Assign a Gaussian weight to k+e corrected galaxies:

$$w \propto \exp\left(-\frac{(z - z_{targ})^2}{2 \cdot 0.15^2}\right)$$

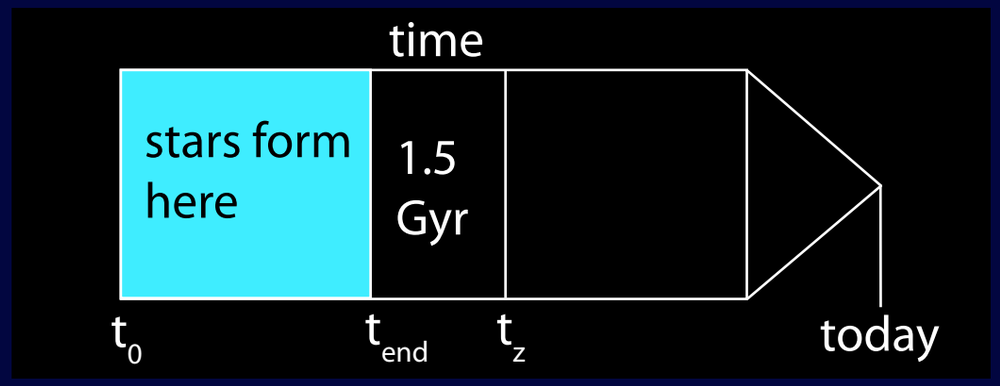
- Plot symbol size is proportional to the weight

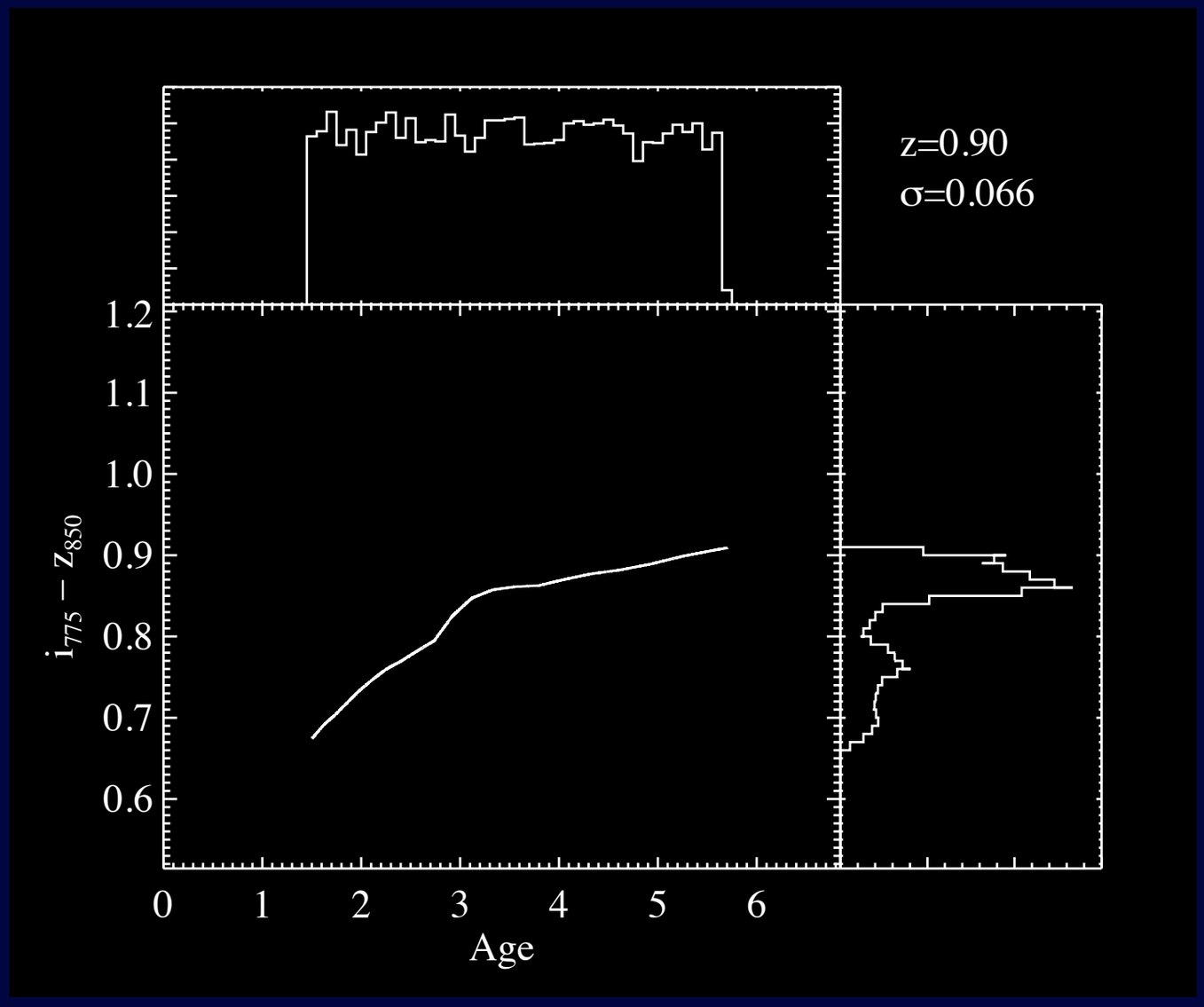


Field early-type hosts are similar to cluster early-type hosts



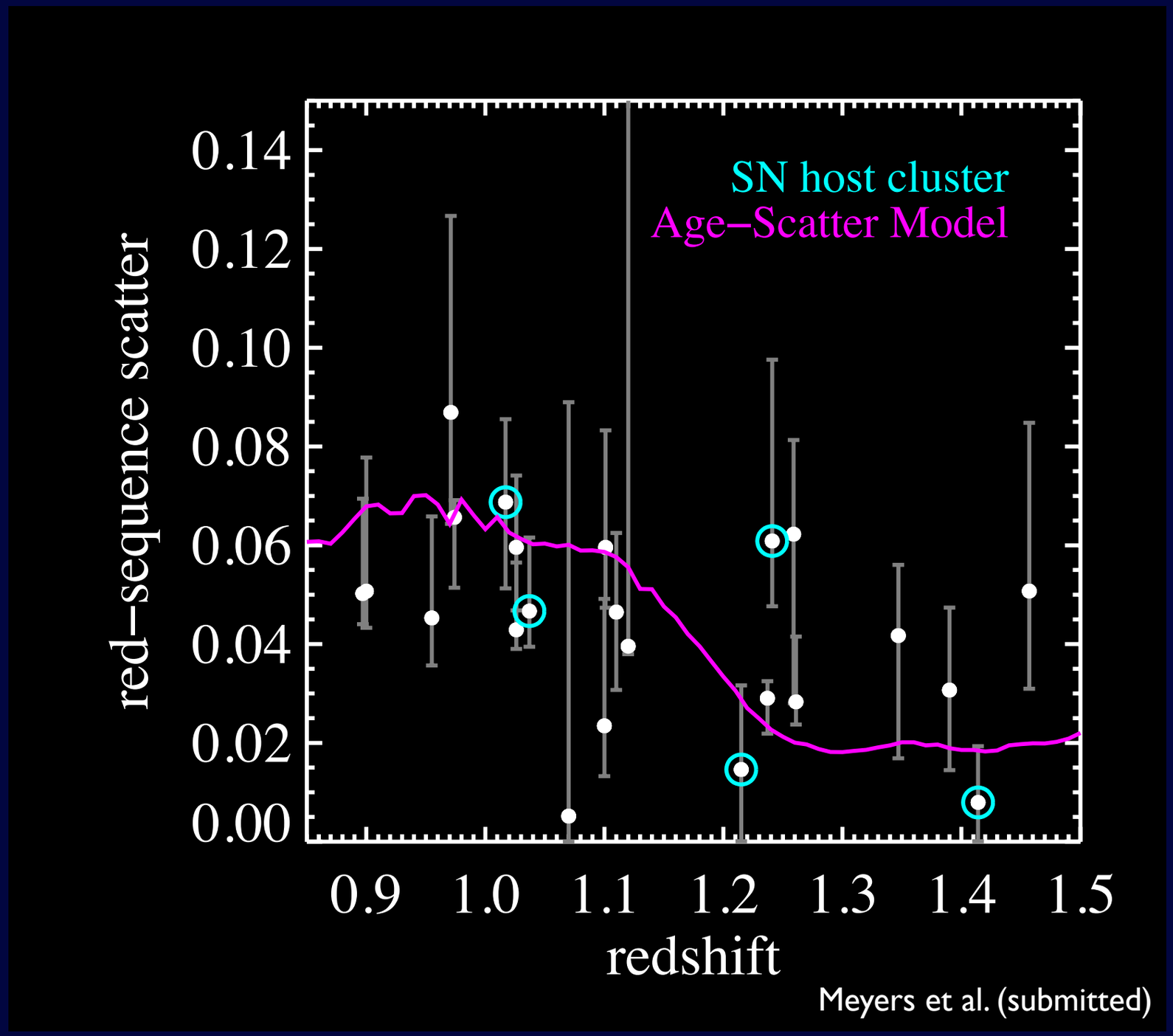
Dust Constraints: Age-scatter model (Bower et al. 1992, van Dokkum & Franx 2001)





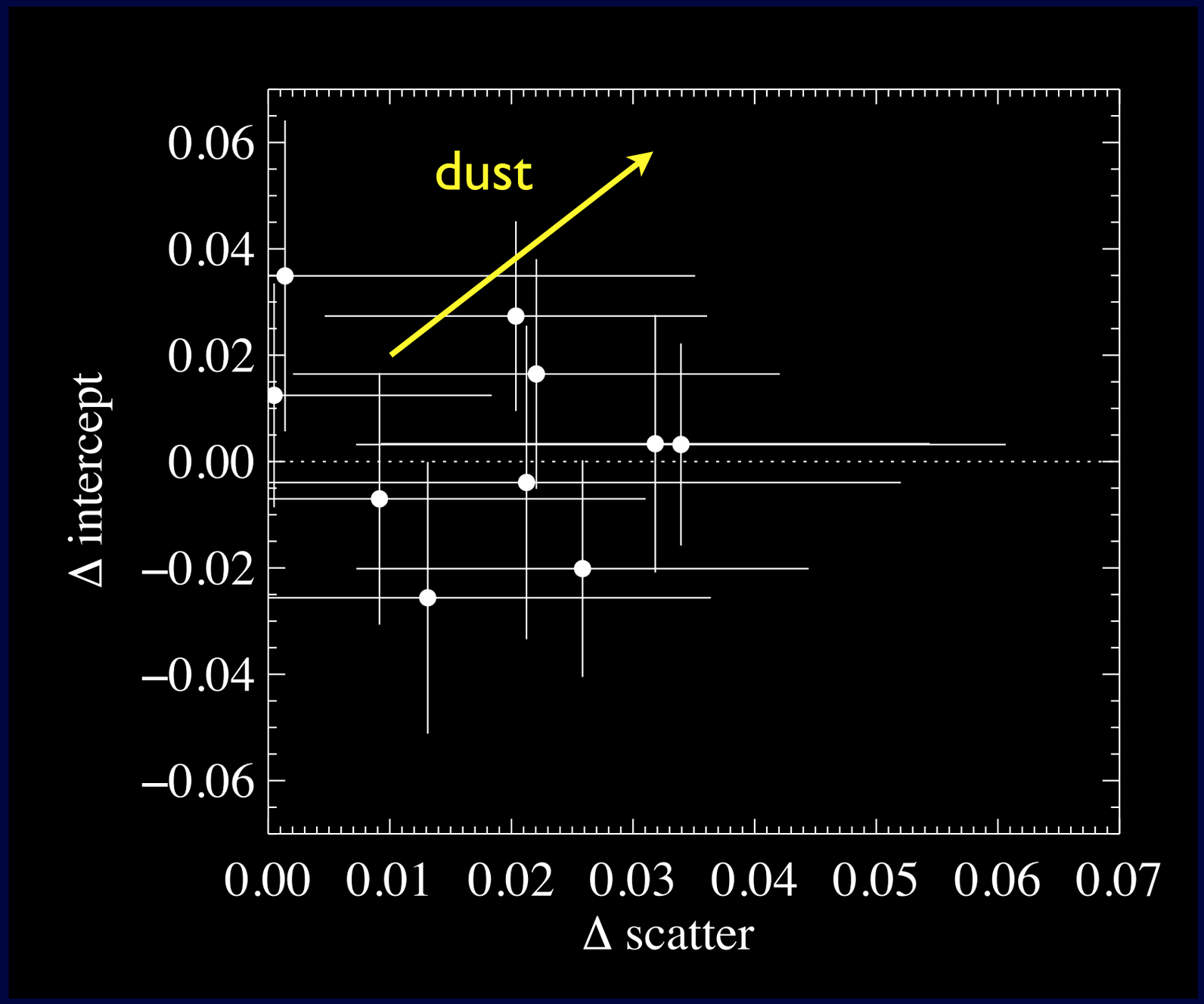
- Age, metallicity, and dust all affect galaxy color
- Metallicity is responsible for the slope of the red sequence.
- Model: differences in age produce scatter.
- Galaxies form in δ-function starbursts uniformly distributed between (t_0,t_{end}) with $t_{end} < t_z$, the age of the universe at the cluster redshift.
- $t_z - t_{end}$ is set to 1.5 Gyr to allow time for morphological evolution

Many clusters have small scatter



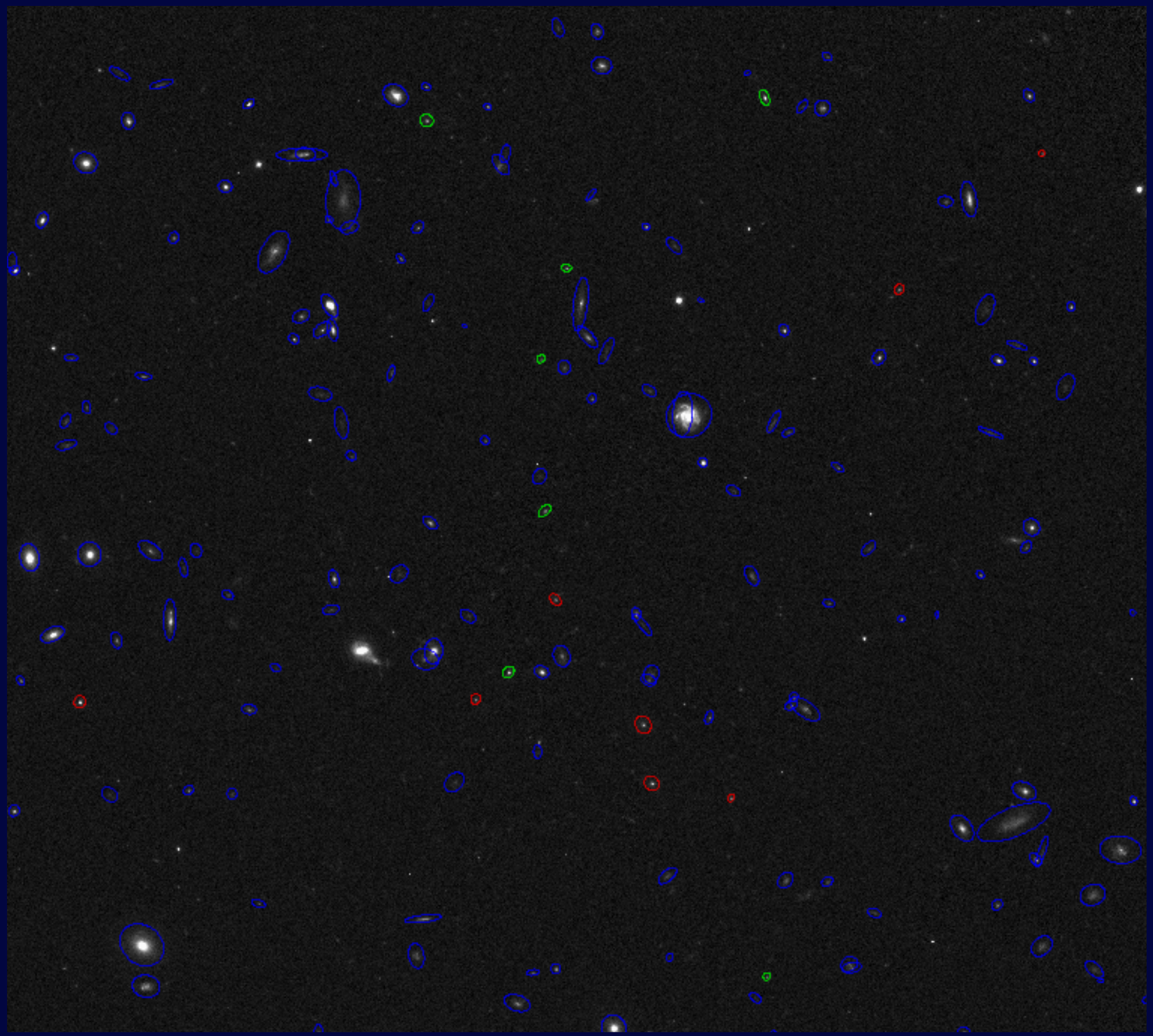
- Clusters with scatter smaller than the model are unlikely to be reddened.
- Rough estimate for clusters which hosted SNe is that dust-attributable scatter is less than 0.01 magnitudes.

Differences in scatter and intercept are not consistent with dust

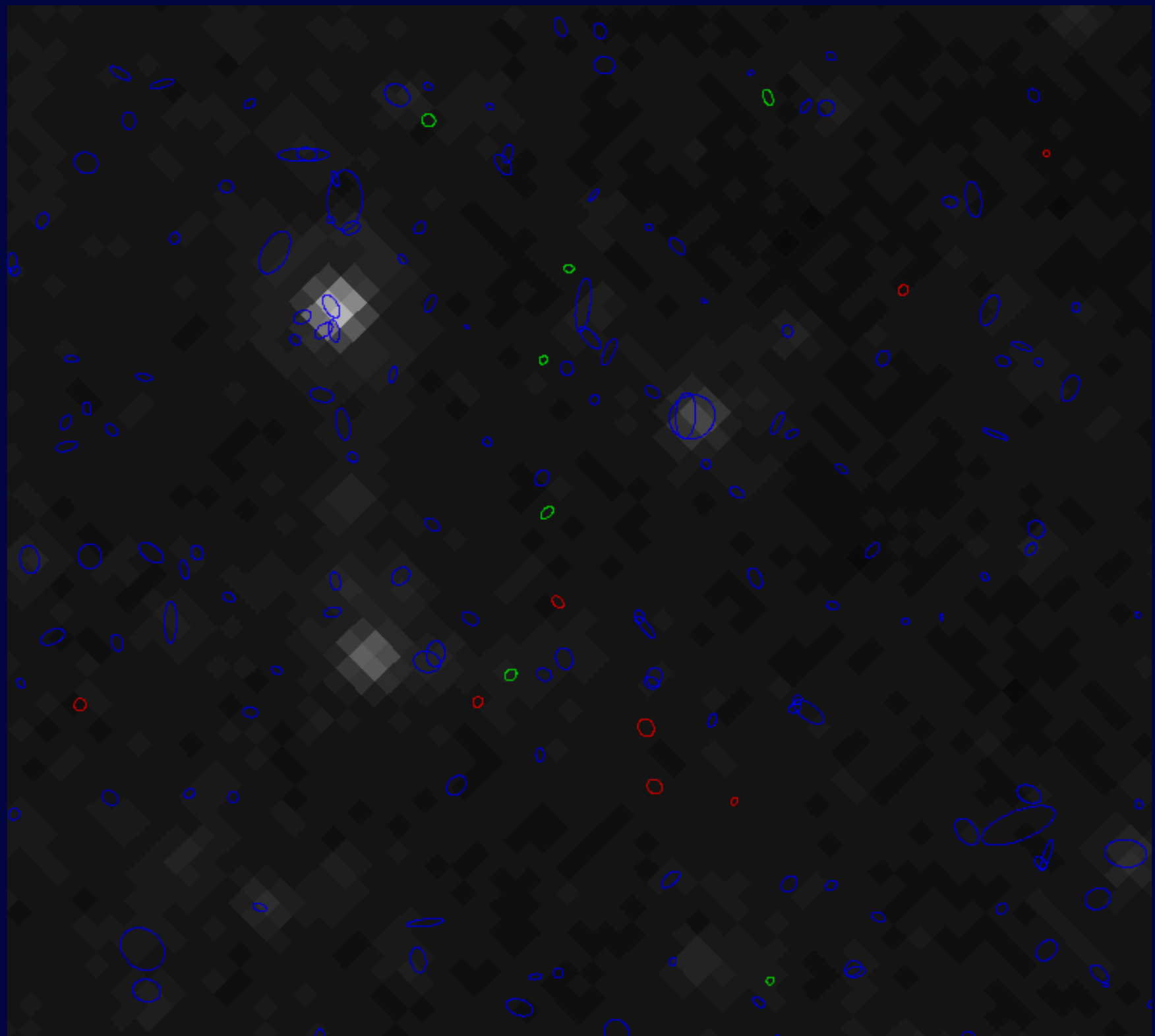


- Dust, if present, should increase both the intrinsic scatter and intercept of red sequences.
- Look at cluster pairs with $|\Delta z| < 0.02$
- Increased scatter is not correlated with a redder intercept.

Dust emission in Spitzer 24 μm images

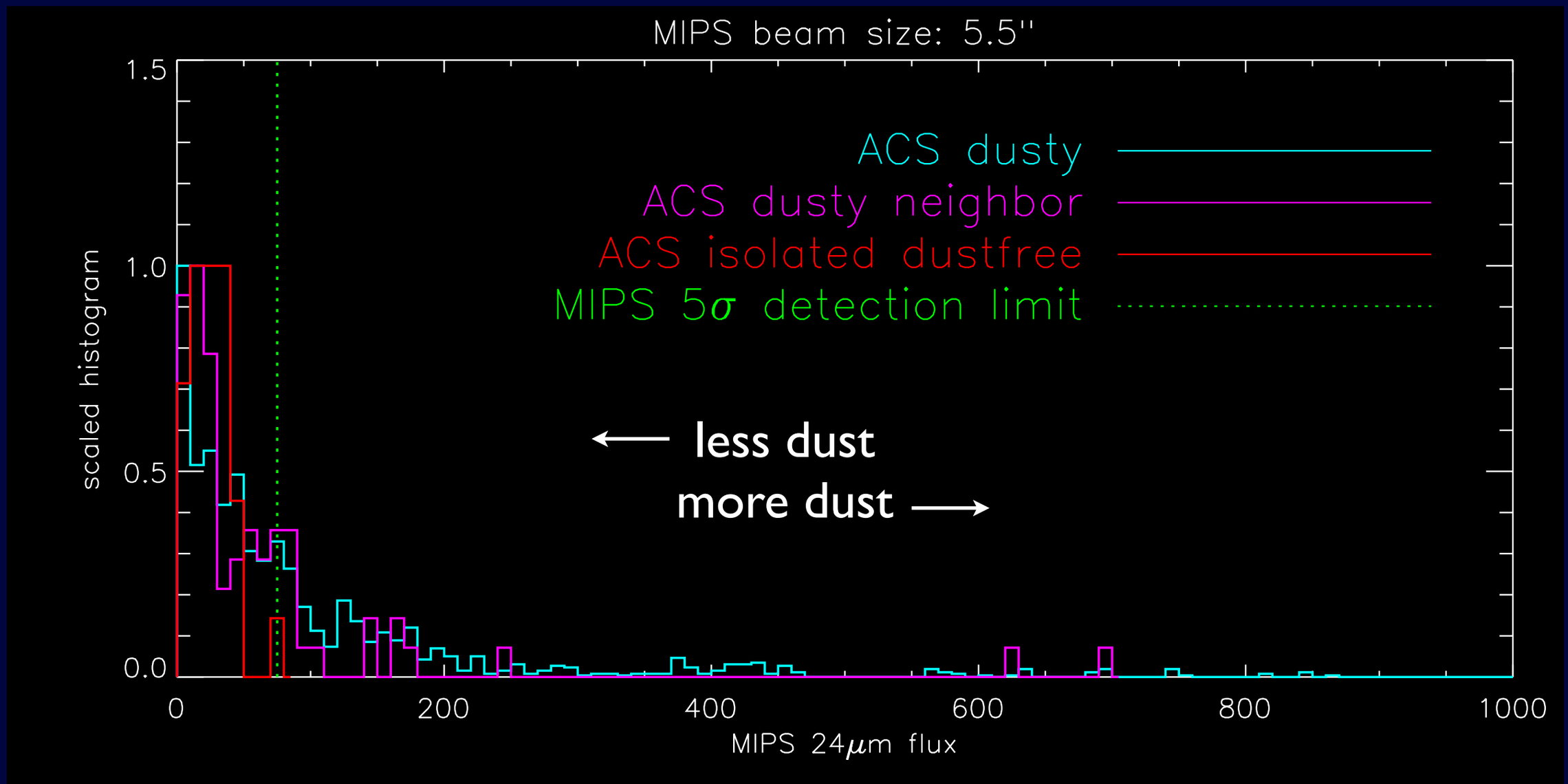


Dust emission in Spitzer 24 μm images



No dust detected in isolated red-sequence galaxies

- Seven clusters have 24 μm Spitzer MIPS images
- Isolated red-sequence members are below the MIPS detection limit (red histogram)

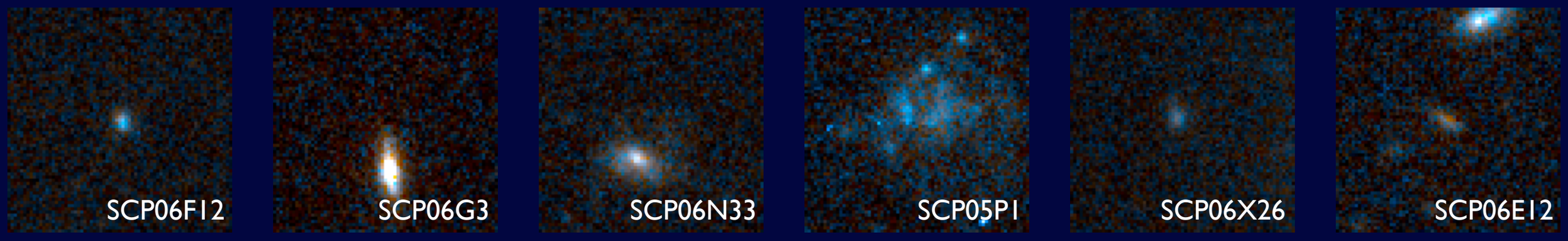


Outline

- SN Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations

HST Cluster SN Survey Hosts

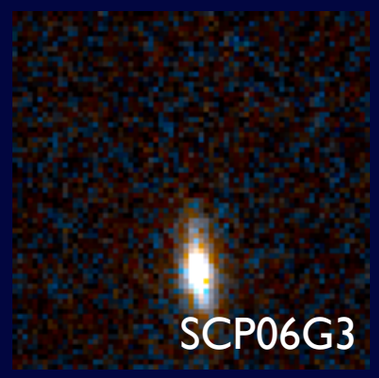
Late-type hosts



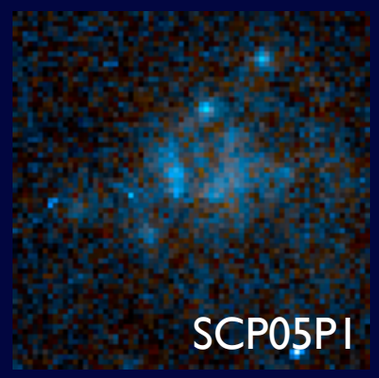
HST Cluster SN Survey Hosts

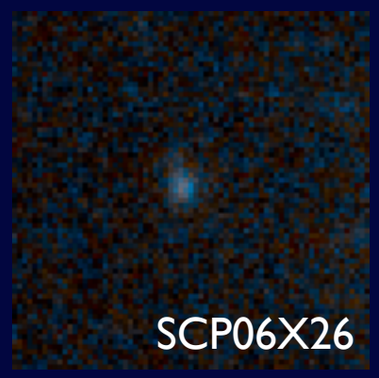
Late-type hosts

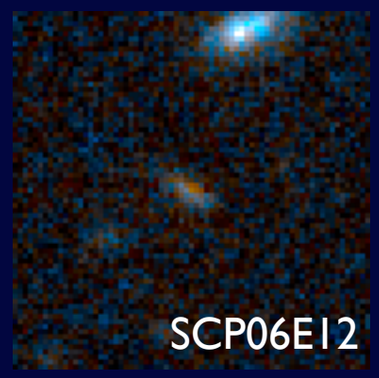

SCP06F12


SCP06G3

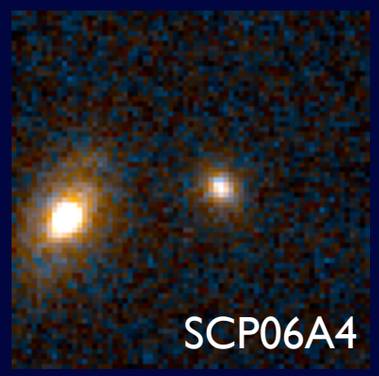

SCP06N33

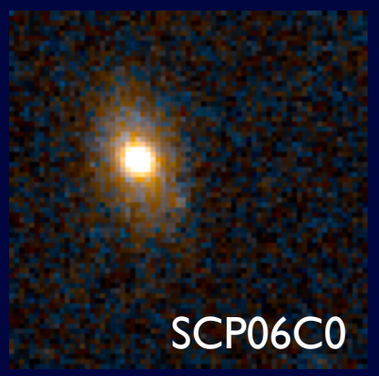

SCP05P1


SCP06X26

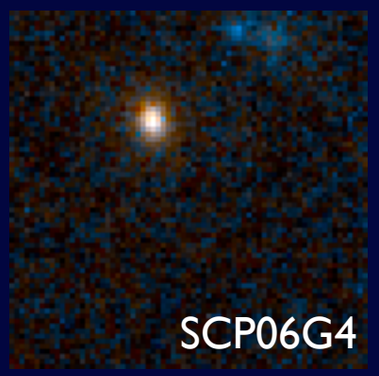

SCP06E12

Field early-type hosts


SCP06A4


SCP06C0

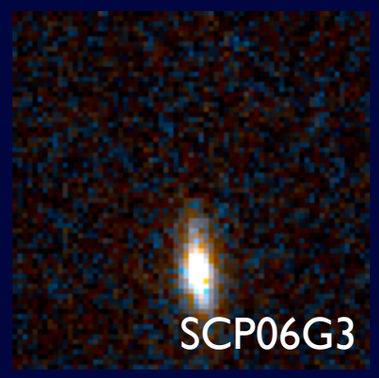

SCP05D6


SCP06G4

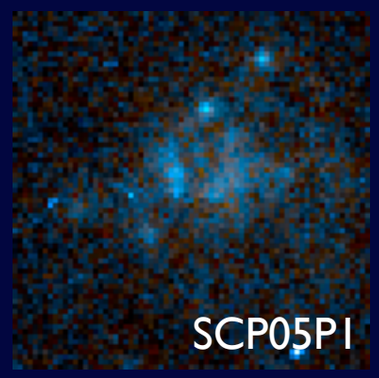
HST Cluster SN Survey Hosts

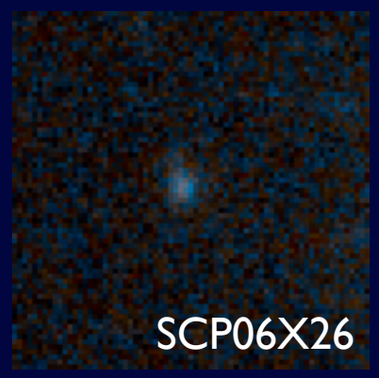
Late-type hosts

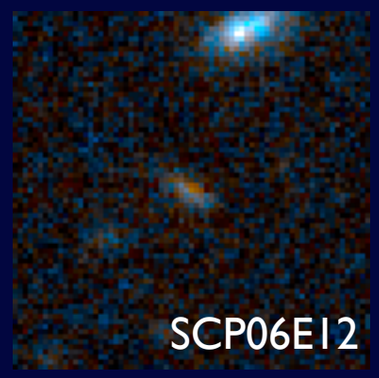

SCP06F12


SCP06G3

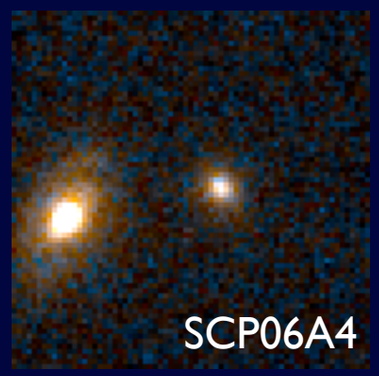

SCP06N33

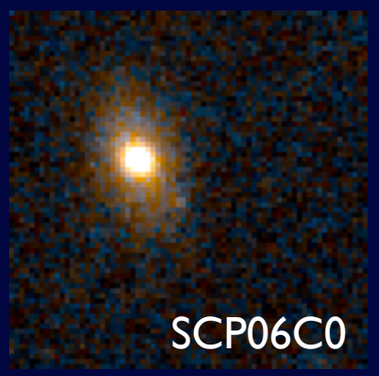

SCP05P1


SCP06X26

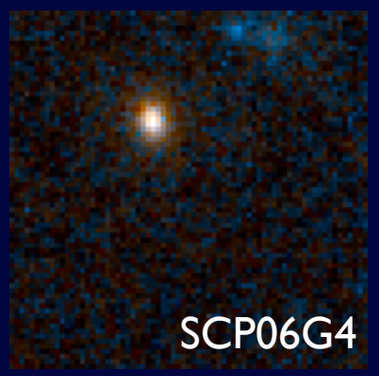

SCP06E12

Field early-type hosts

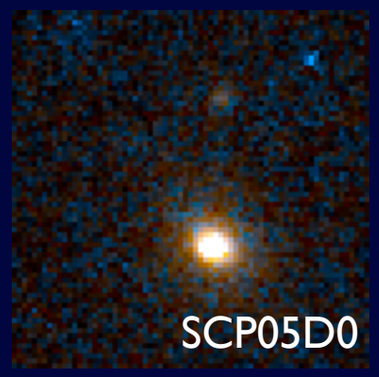

SCP06A4

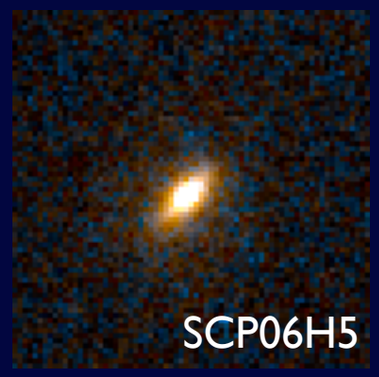

SCP06C0


SCP05D6

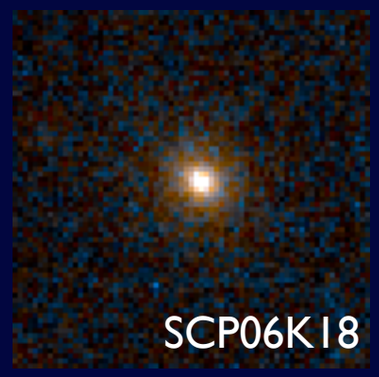

SCP06G4

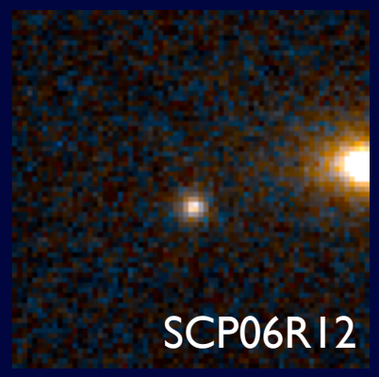
Cluster early-type hosts

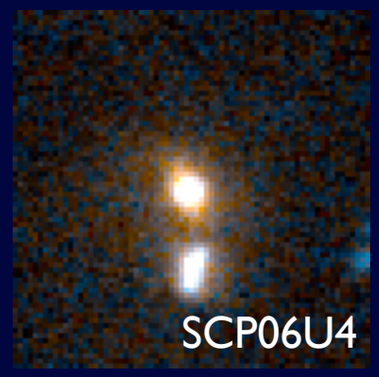

SCP05D0


SCP06H5

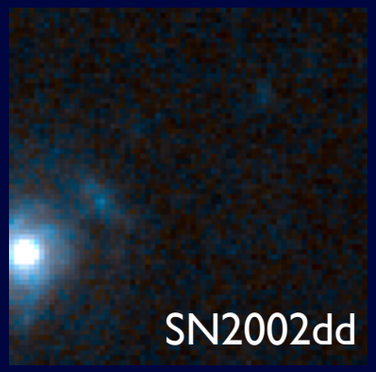

SCP06K0

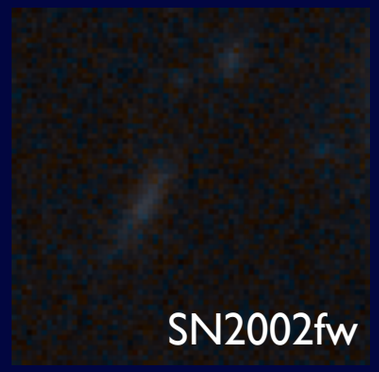

SCP06K18

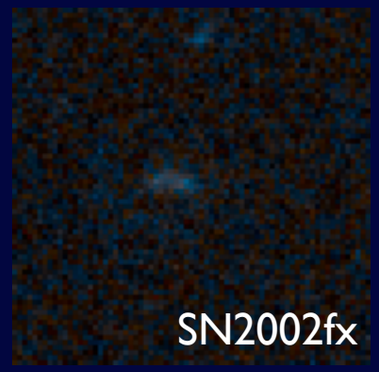

SCP06R12


SCP06U4

Late-type hosts


SN2002dd


SN2002fw


SN2002fx


SN2002ki

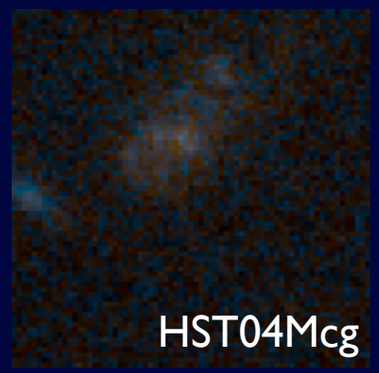

SN2003eb

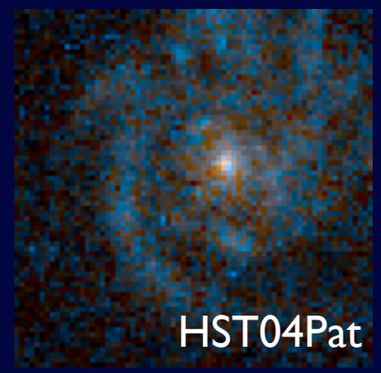

SN2003aj

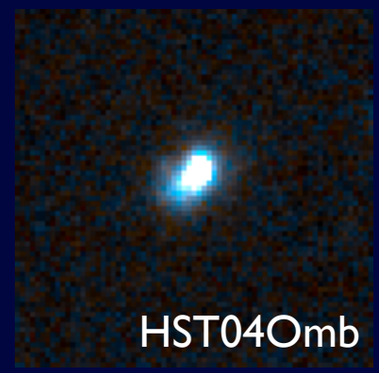

SN2003ak


SN2003dy


HST04Eag

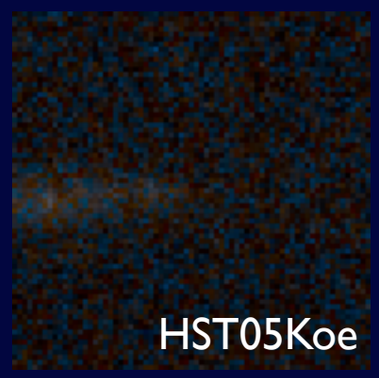

HST04Mcg

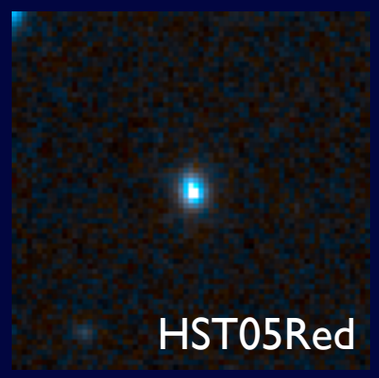

HST04Pat


HST04Omb


HST05Fer

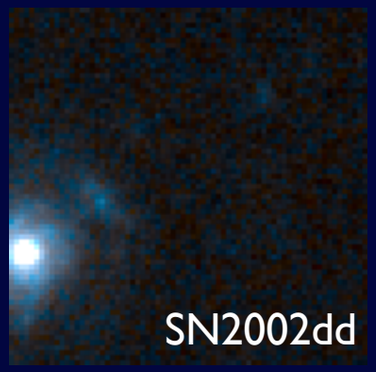

HST05Gab

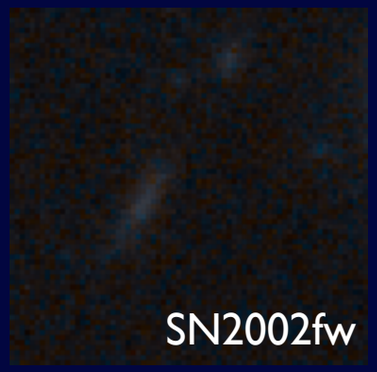

HST05Koe

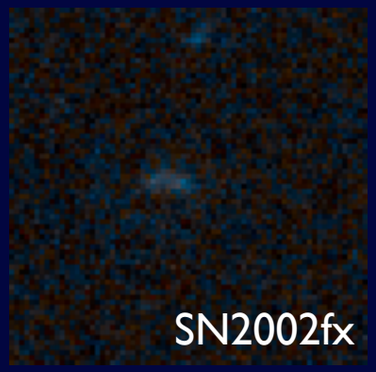

HST05Red


HST05Str

Late-type hosts


SN2002dd


SN2002fw


SN2002fx


SN2002ki

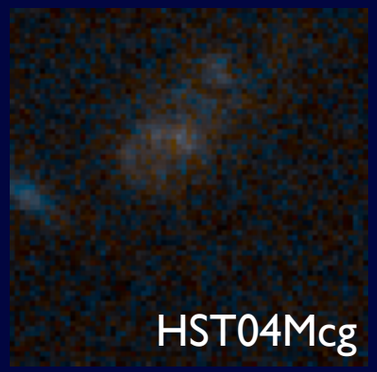

SN2003eb

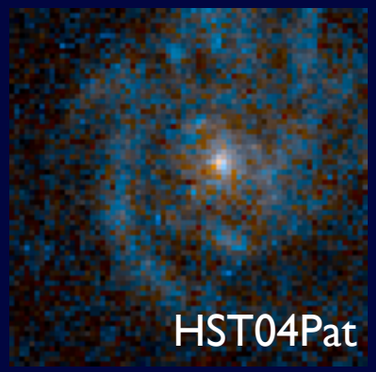

SN2003aj


SN2003ak


SN2003dy

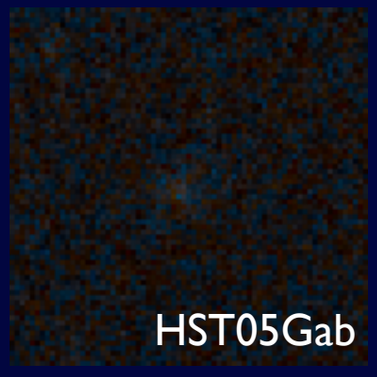

HST04Eag

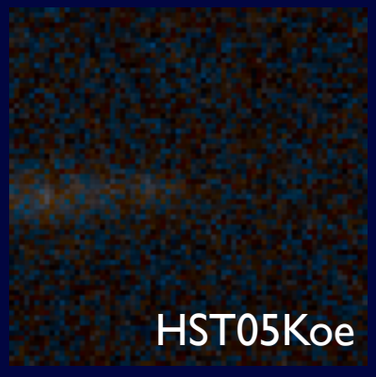

HST04Mcg

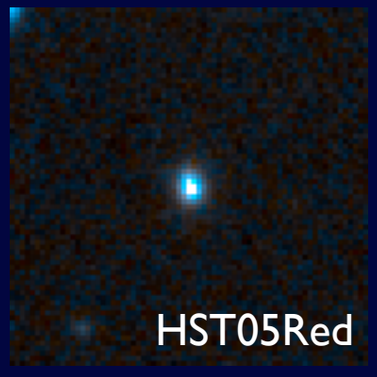

HST04Pat


HST04Omb

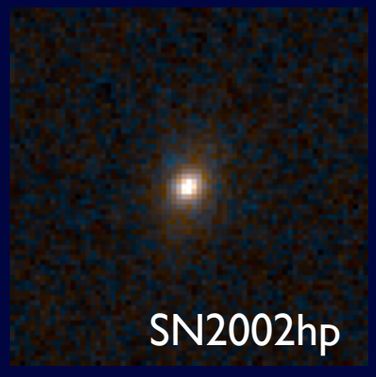

HST05Fer


HST05Gab


HST05Koe


HST05Red

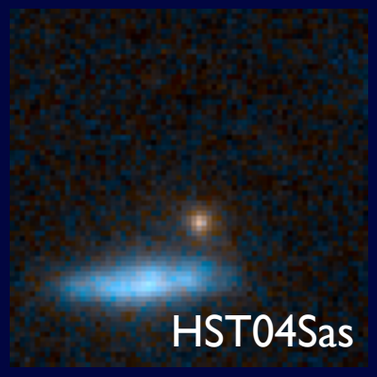

HST05Str

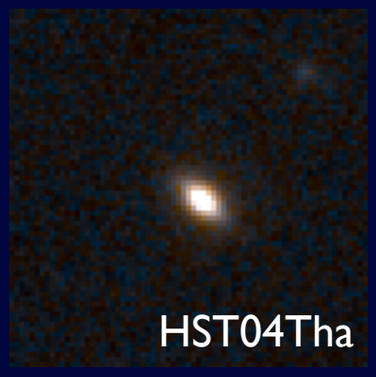

SN2002hp

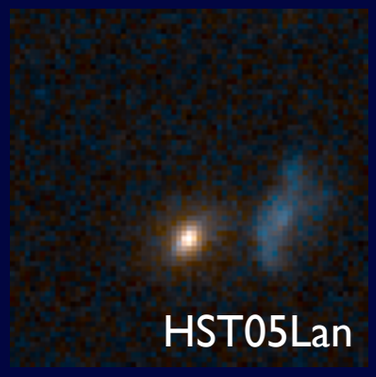

SN2003az


SN2003es


SN2003XX

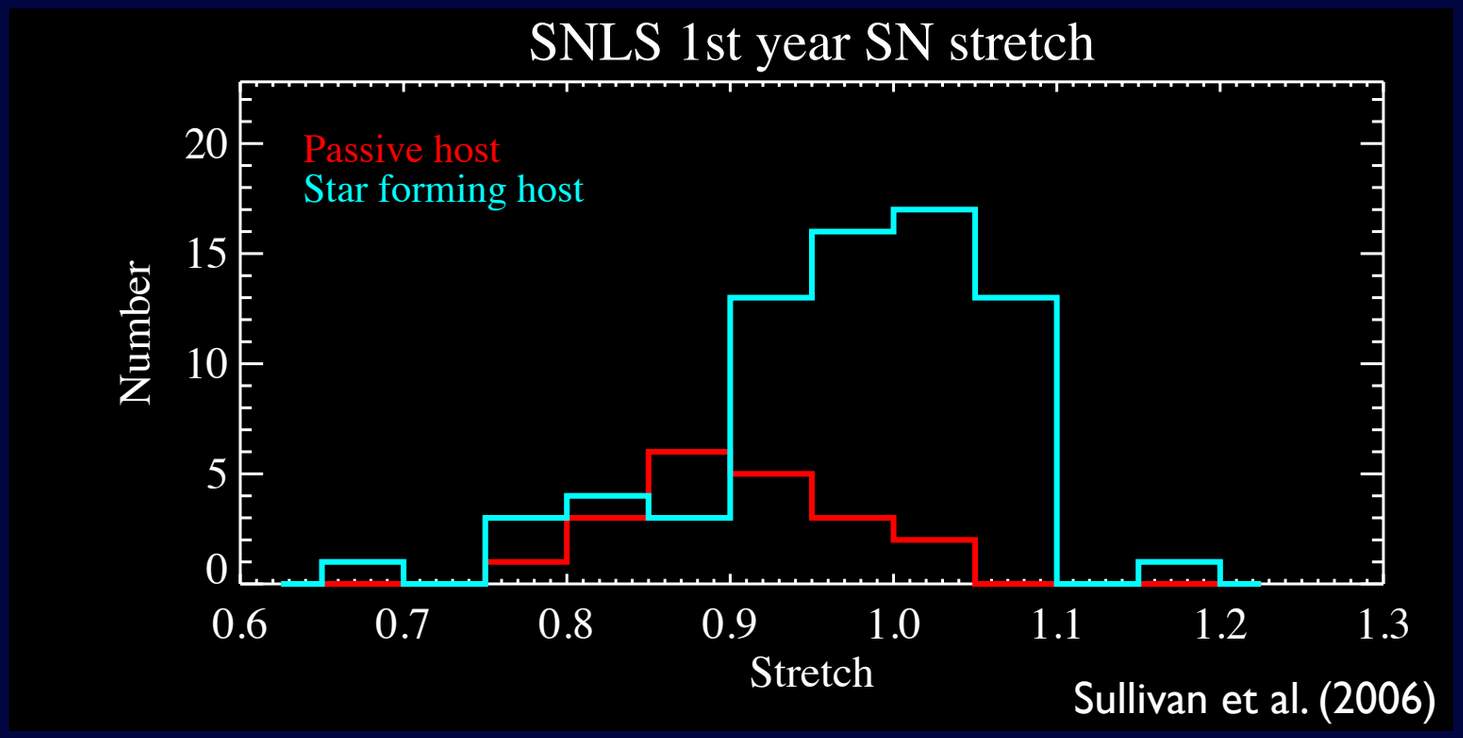

HST04Sas

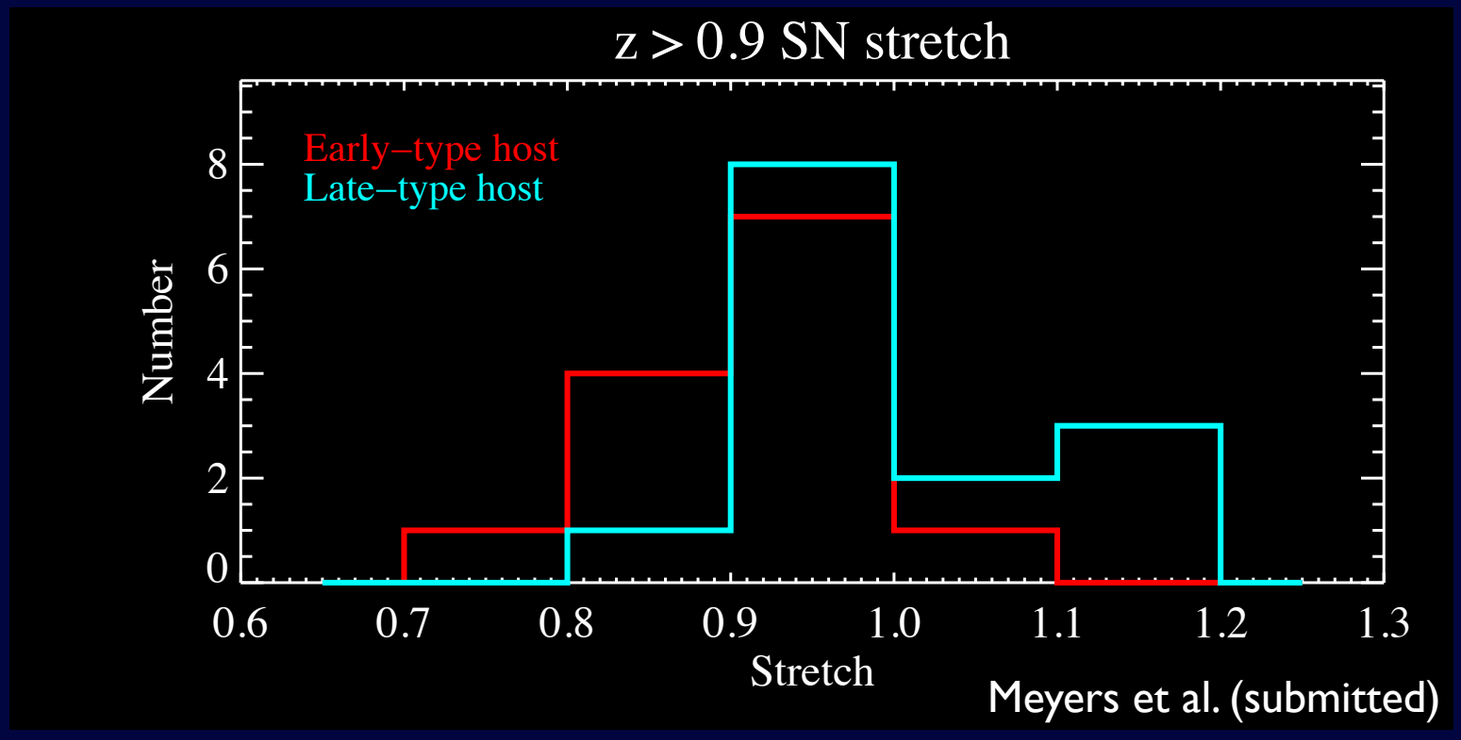

HST04Tha


HST05Lan

Early-type hosts

Stretch correlation with host exists at z > 0.9





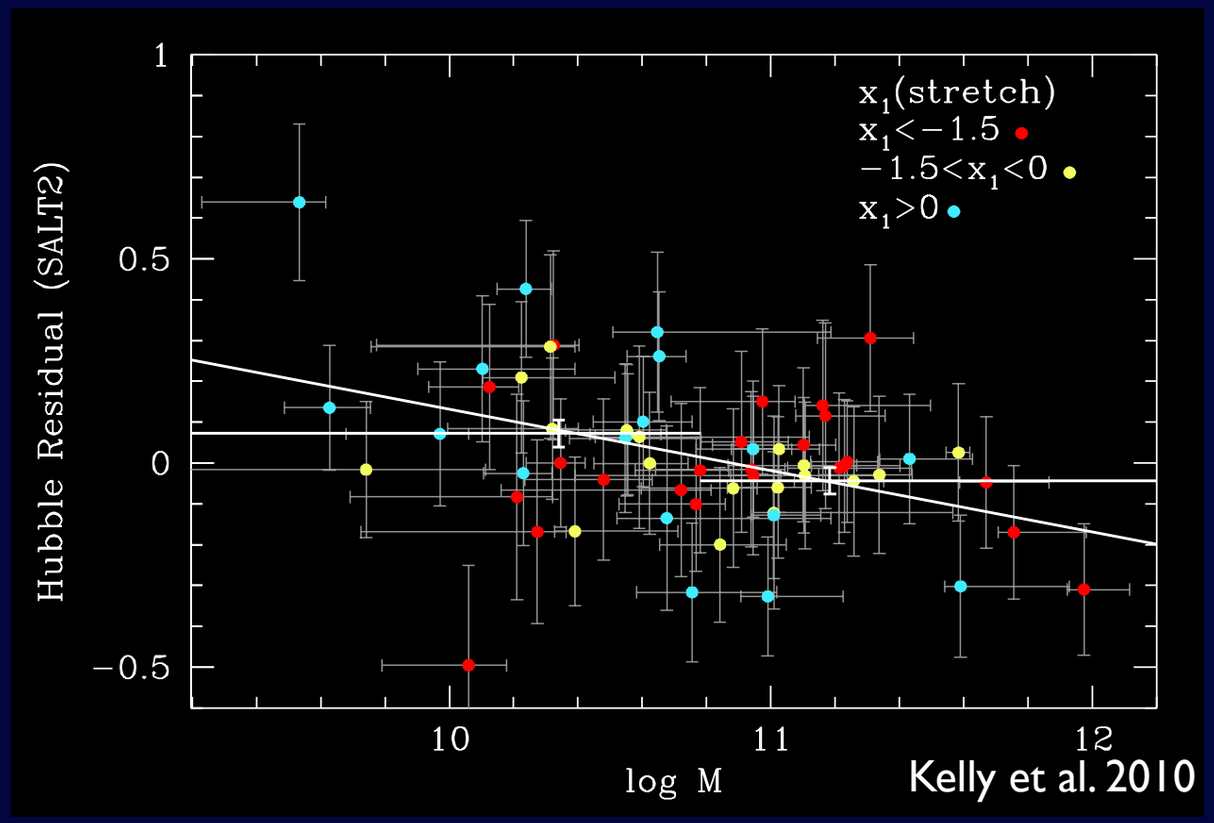
Kolmogorov Smirnov - probabilities

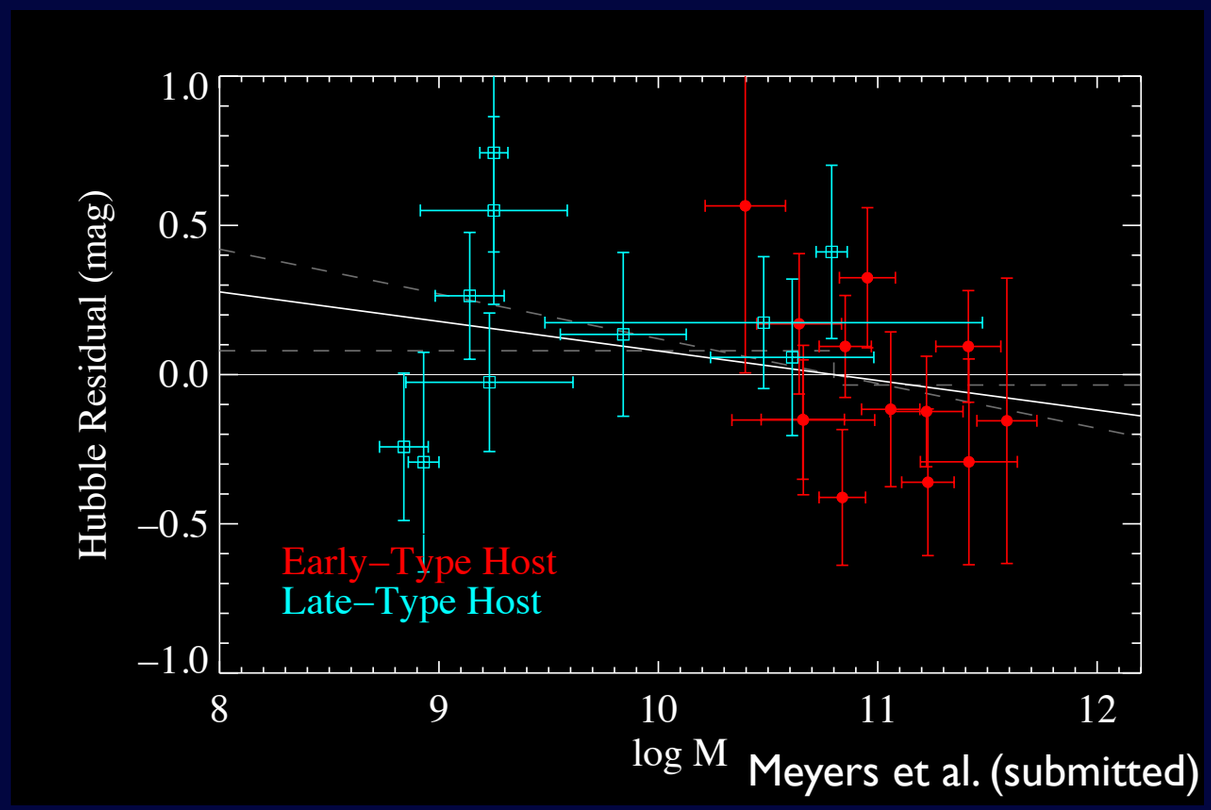
z > 0.9 ETG to z > 0.9 LTG: < 1%

z > 0.9 ETG to SNLS passive: 92%

z > 0.9 LTG to SNLS star-forming: 63%

Corrected Hubble residuals depend on host mass





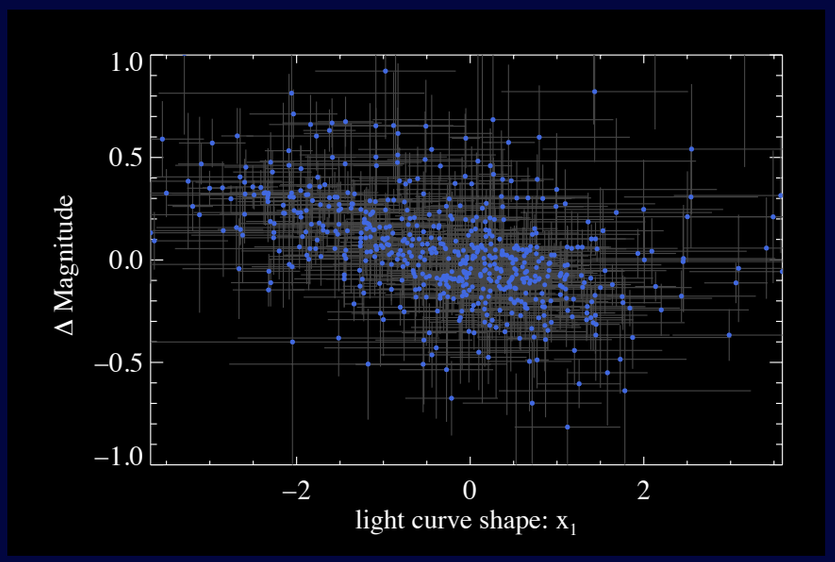
- Brighter SNe in more massive galaxies.
- Brighter SNe in passive galaxies.
- Early-type host masses from i_{775} and z_{850} photometry
- Late-type host masses from Thomson and Chary (2011).
- Host galaxy demographic shift must be accounted for.

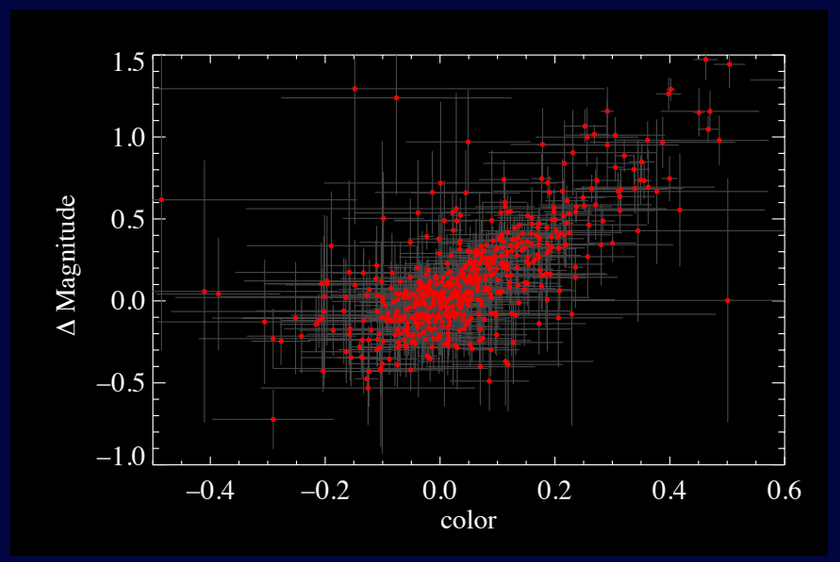
SN Ia calibration 102

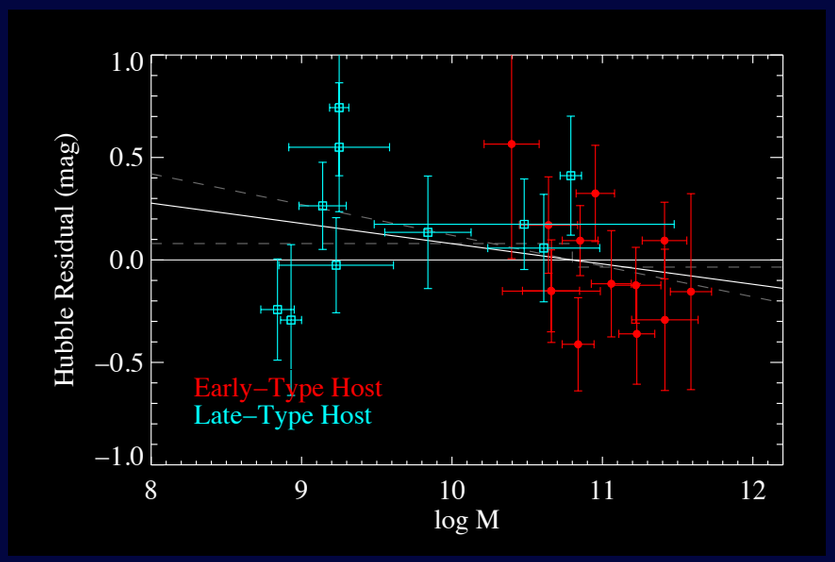
- Distance modulus parameterization (Suzuki et al. 2011):

$$\mu_B = m_B - M + \alpha x_1 - \beta c + \delta \cdot P\,(M < M_{\rm split})$$

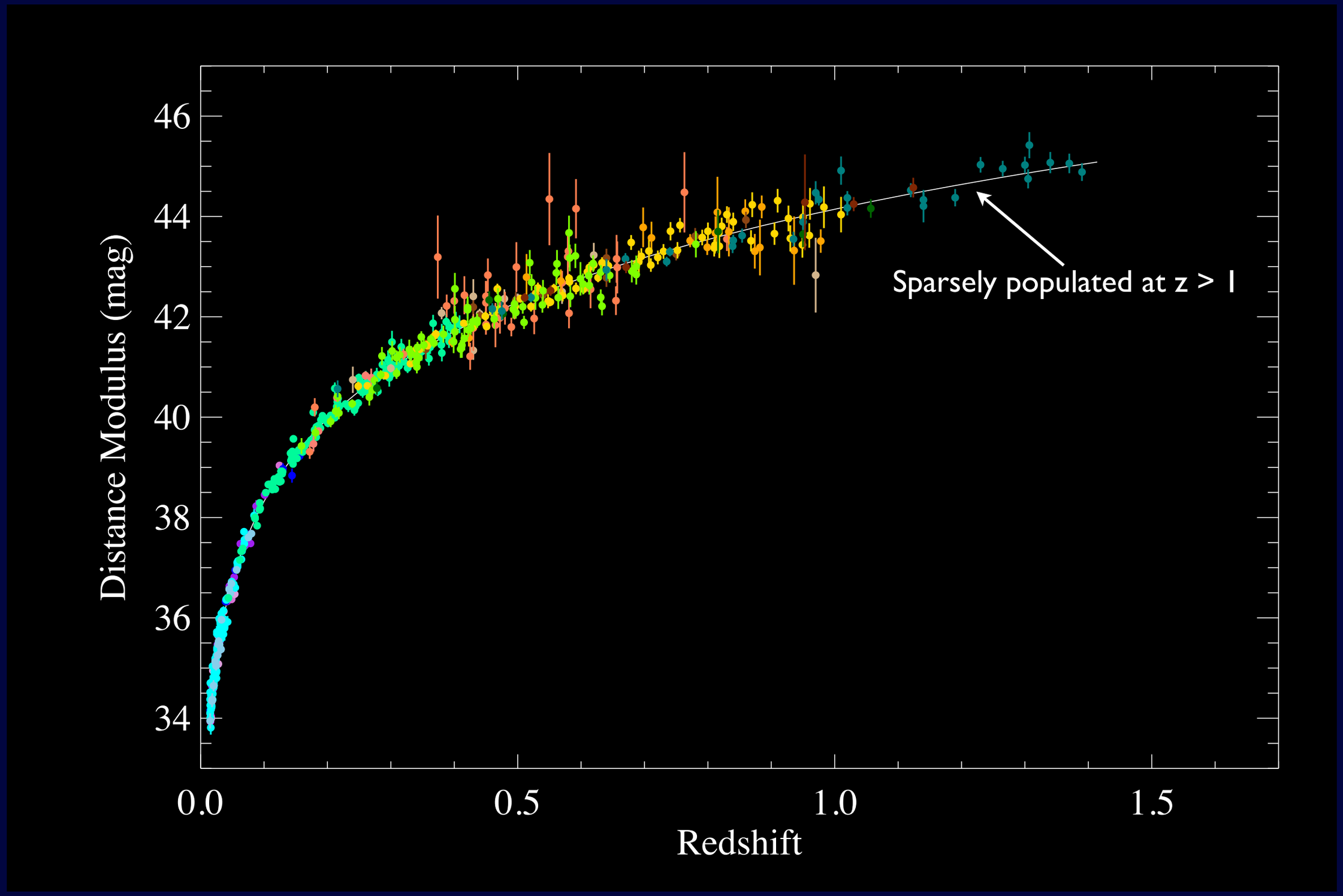
- α: parameterizes the light curve shape -- brightness relation
- β: parameterizes the SN color -- brightness relation
- δ: parameterizes the host-mass -- brightness relation



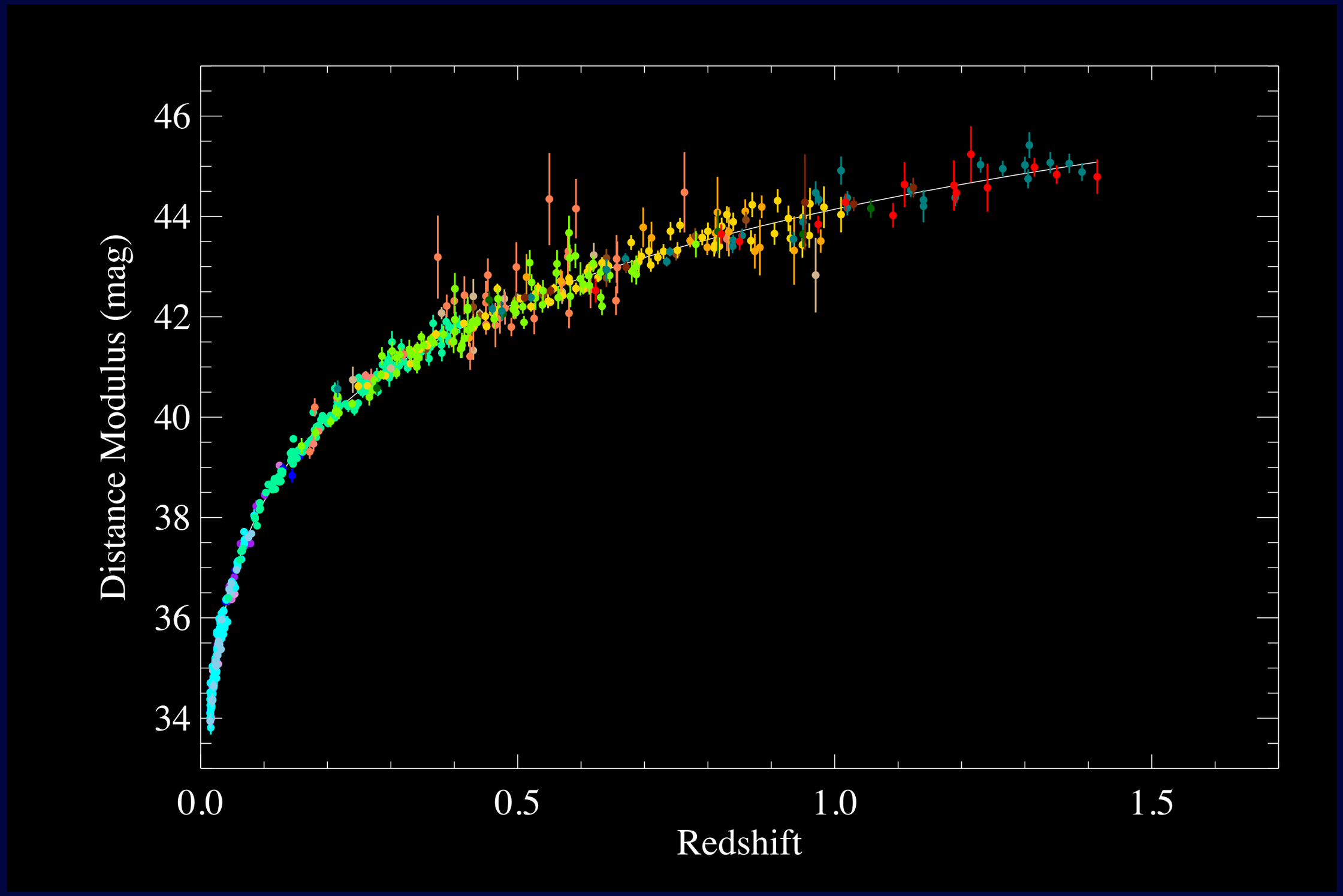




SN Ia Compilation

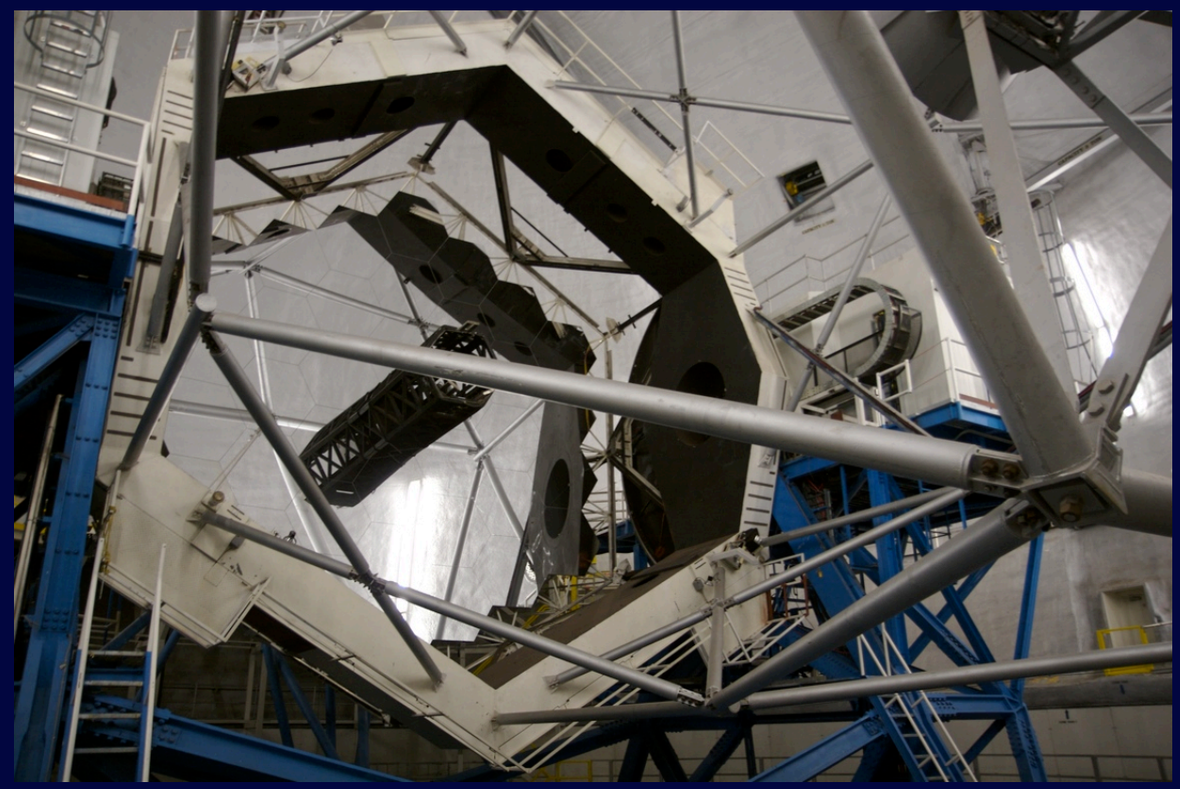


SN Ia Compilation

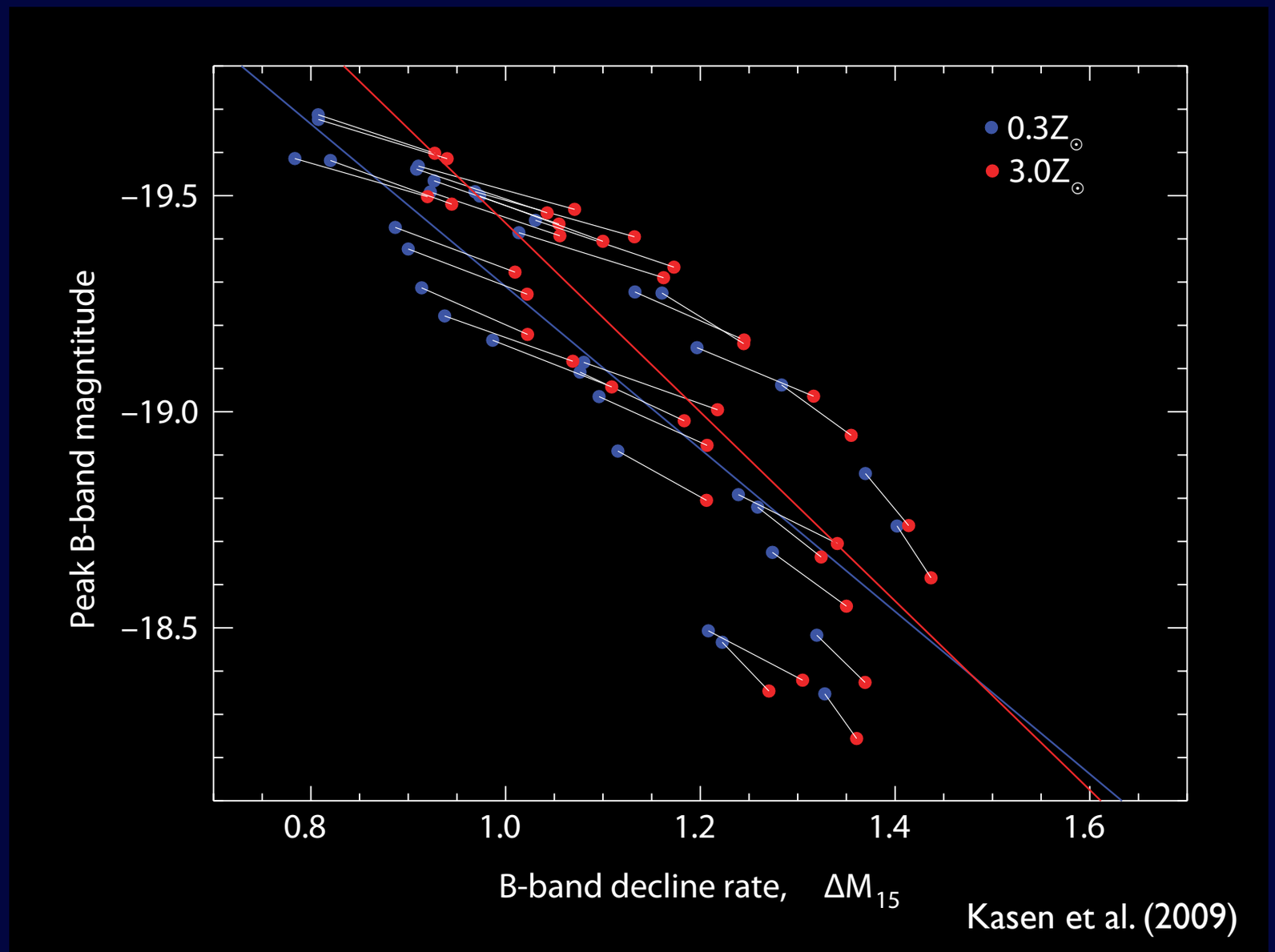


Outline

- SN Ia basics and cosmology
- Using host information to improve efficiency
- Targeting hosts to minimize dust
- Checking host correlations for systematics
- Pinpointing the physics of host correlations



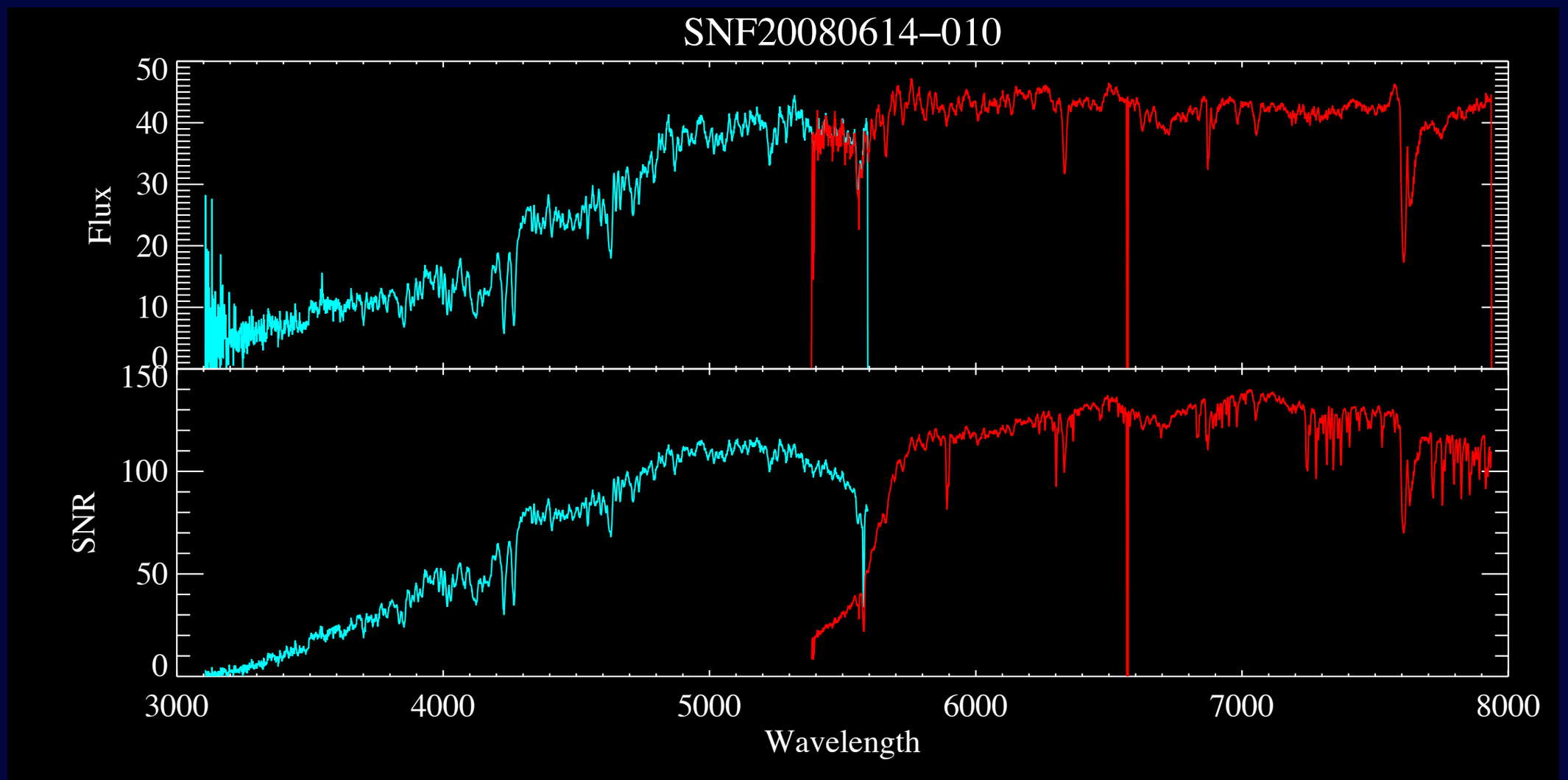
Luminosity trend consistent with theory



- Simulations of C/O white dwarf explosions are consistent with the broader-brighter relation.
- The trace abundances of elements other than carbon/oxygen produces an effect consistent with the host-mass -- Hubble residual relation.

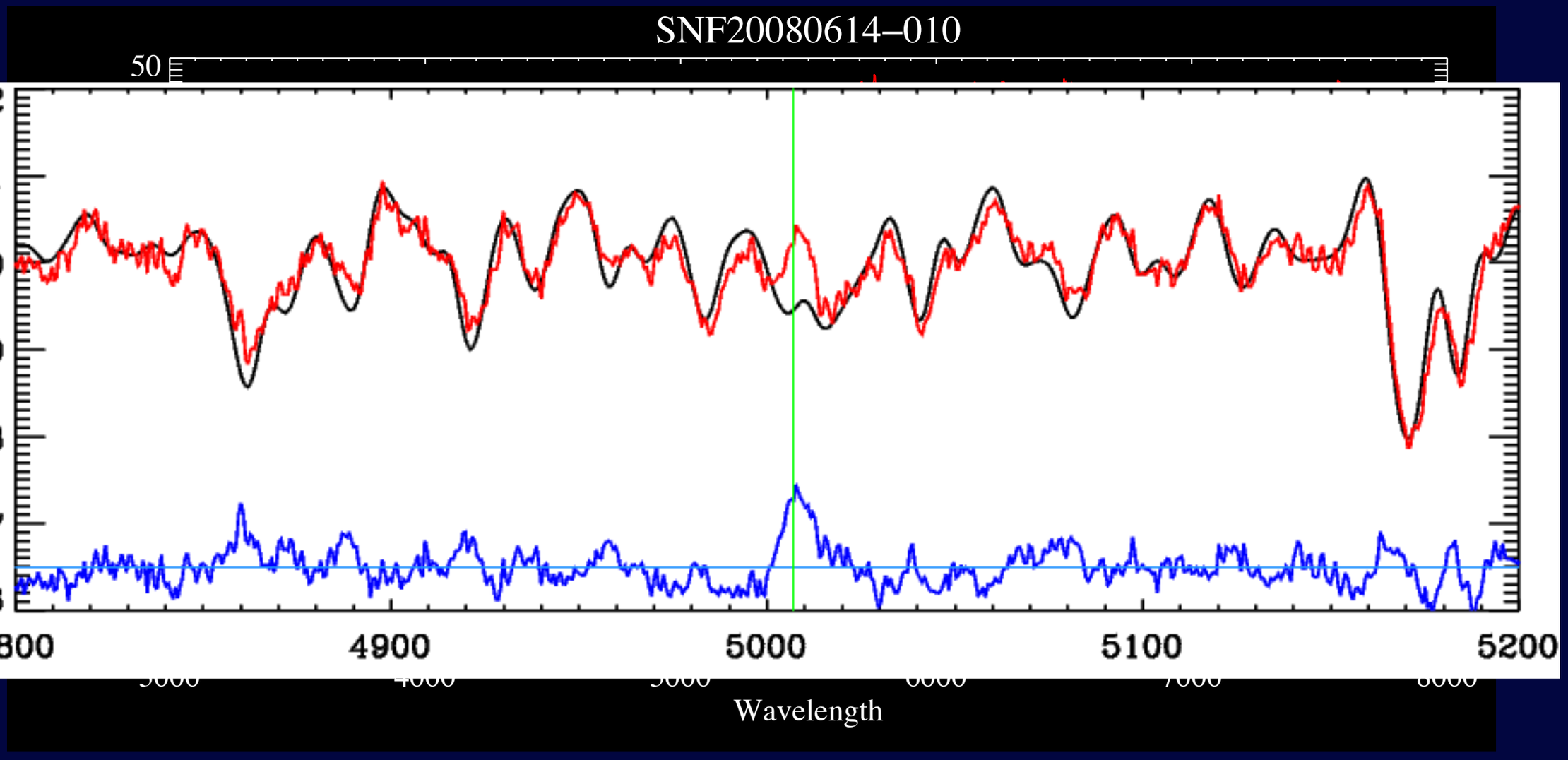
What is the underlying physics of host-galaxy -- SN correlations?

- Use signal-to-noise ratio 100/Å Keck spectra of SN hosts to answer this.
- Measure absorption line indices.
- Infer age, metallicity, and other element abundances.

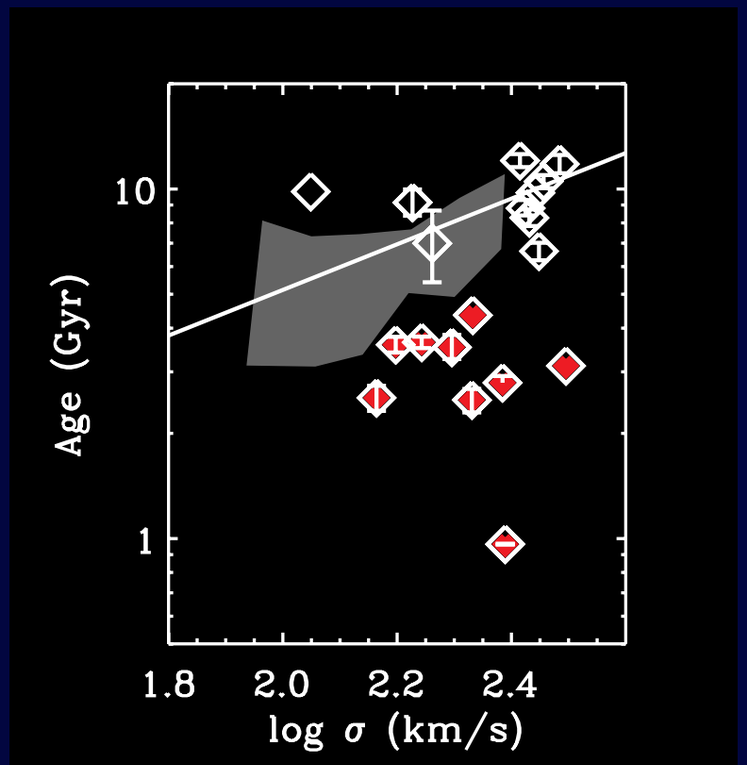


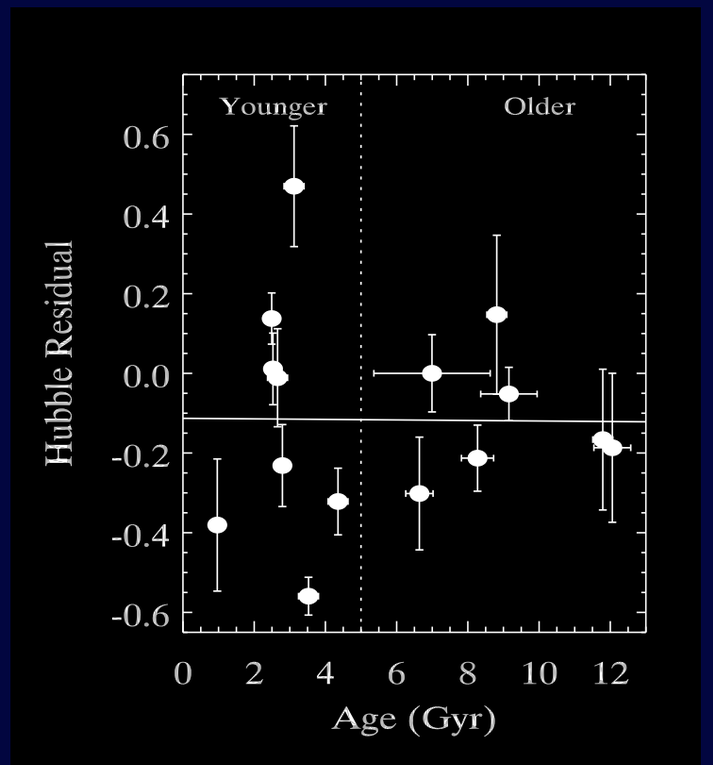
What is the underlying physics of host-galaxy -- SN correlations?

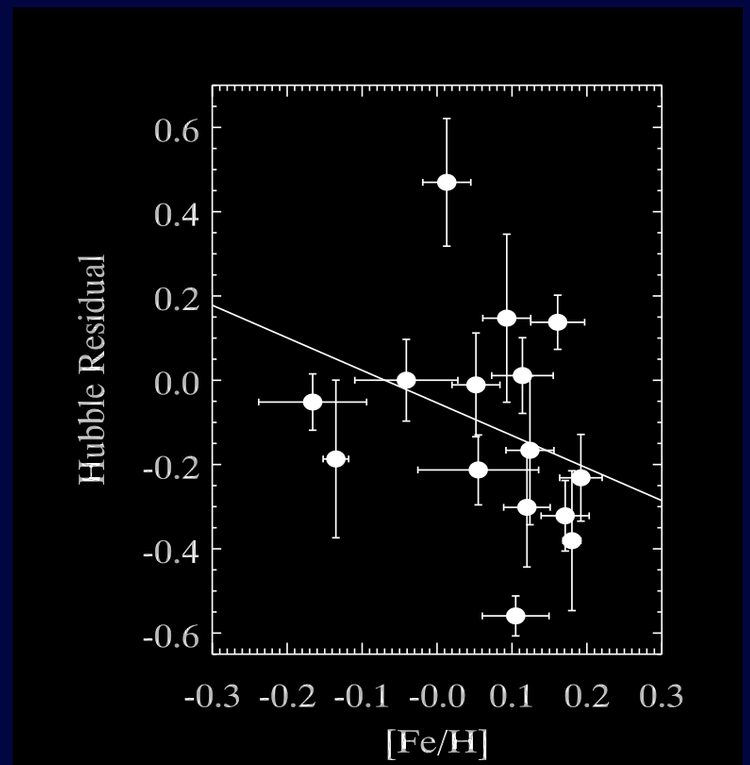
- Use signal-to-noise ratio 100/Å Keck spectra of SN hosts to answer this.
- Measure absorption line indices.
- Infer age, metallicity, and other element abundances.



Preliminary results from SNR 100 data







- Are early-type SN hosts younger than typical early-type galaxies?
- Could old early-type galaxies host SNe Ia with smaller dispersion?
- Do higher metallicity hosts produce brighter corrected SNe Ia?

Conclusions

- Cluster early-type hosted SNe are Type Ia and relatively free of dust.
- The host galaxy type -- SN Ia stretch relation exists at high redshift
- The host galaxy stellar mass -- SN Ia Hubble residual relation is consistent with high-redshift observations.
- We are working to pinpoint the underlying physics of SN Ia -- host galaxy correlations.